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EXPERIMENTAL STUDIES OF EMBRYONIC BONE TRANSPLANTATION

By

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Since *Bert* nearly one hundred years ago (1863) first suggested that embryonic tissues often could be grafted successfully to animals of the same species much work has been done on embryonic tissue transplantation An extensive list of references of the early investigations can be found in the monograph by *Bosaeus* (1926)

The variable results of such studies were succinctly summarized by the statement that embryonic tissues may survive homogenous transplantation in whole or in part permanently temporarily or not at all (*Willis* 1935)

A review of the accessible literature at the outset of this investigation disclosed no previous work specifically on the subject of embryonic bone transplantation and on its possible use as homogenous bone graft material It has been stated that the mild reaction to homoimplanted embryonic tissue has led to exaggerated statements and great expectations but that no greater hope of success can be expected from the homotransplantation of embryonic than adult tissues (*Dempster* 1957) However a number of theoretical reasons could be marshalled to justify a special study of the homogenous transplantation of embryonic bone and the chief ones were a) the relatively low antigenicity of embryonic tissues b) the maintenance of vigorous osteogenesis of embryonic bone in tissue culture with homogenous and heterogenous media c) the possibility that the fate of a homotransplant might be partly determined by the site of transplantation and therefore that embryonic bone might fare better in the partly protected bed of the host skeleton d) that some at least of the transplant might survive the so-called "critical period of *Woodruff* e) that even if the embryonic bone was ultimately destroyed

in sterile Petri dishes and kept at room temperature until the host animal had been made ready to receive the graft The delay varied from a quarter of an hour to about one and a half hours

There is a great difference in the size of the chick tibiae at different ages of incubation Only 4 tibiae of 18 days old embryonic bone sufficed to fill a standard defect whereas 40 tibiae of bone of 12 days incubation were required In some cases in order to destroy the vitality of the embryonic bone before it was transplanted the fragments were heated to 50 C for 20 minutes in Krebs Ringer s solution (bicarbonate free)

Operative technique In all animals general ether anaesthesia was employed and the incisions were vertical in the midline over the dorsal aspect of the pelvis The skin was undercut and retracted to expose an adequate expanse of the sacrum The periosteum was elevated and pushed aside in the selected areas and circular trephine defects either two or four in number were made with a hand driven drill of 7 mm internal diameter One or two defects were made on one side of the sacrum and corresponding contralateral defects were made on the opposite side equidistantly from the midline The defects were made through the full thickness of the sacrum and the bone plugs were re moved One defect was filled with embryonic bone material obtained as described earlier The opposite defect used in all the cases as a standard control was filled by autogenous bone graft material The autogenous bone grafts were obtained from the cores of bone removed with the trephine drill These plugs were divided with scissors into small bits to give an autogenous material roughly comparable in size and quantity with the embryonic material

In 12 animals (nos 6–17 incl) in which four defects were drilled the two additional defects were used as supplementary controls The two extra defects were made as described above and placed equidistantly from the midline One supplementary defect was left empty to deter mine whether such a defect might heal without any bone graft material implanted The other was implanted with preheated embryonic bone to see if previous devitalization made any difference to the fate of the embryonic bone or the healing of the defects

With some care the operation was easy and almost bloodless The wounds were sutured in most instances with one layer of silk or wire and no dressings were employed No pressure nor immobilization was necessary

The aseptic precautions during the operation were fairly elaborate in the beginning but were less stringent in the later cases Variations

from 12 day old embryos was used In the remaining 30 of the 49 cases other transplantations either soft tissue or other bone defect trans plantations were performed in each animal in addition to the standard 2 bone defect operation In 18 of the 30 cases 12 day embryonic bone was used and in 12 of the 30 cases 4 sacral holes were drilled In these 12 animals with the 4 defects the embryonic bone used as graft material was derived from 12 day embryos in 2 cases 16 day in 5 cases and 18 day bone in 5 cases

RESULTS

All the animals sustained the operative procedure well and there were no immediate post-operative deaths Only one animal (no 9) de veloped a purulent infection probably due to technical errors and ex cessive operative trauma Twelve animals died before the time planned for sacrifice (nos 10 13 14 15 26 27 28 31 39 40 48 49) No attempt was made to determine the cause of death Any consideration of the possibility of so-called secondary disease (in which the host sickens and may die due to antibodies developed by the homograft in response to host antigens) was considered beyond the scope of this study Ani mals 26 28 40 48 49 died 14 10 6 8 and 10 weeks respectively after operation and death did not affect assessment of the results Regarding the other deaths the healing time was less than the arbitrary six weeks chosen for comparison of the healing of the bone defects Regarding the soft tissue transplants animals 14 15 27 and 31 had none to be exa mined In animals 10 and 13 they had already been recovered for histo logical examination by reoperation before death of the animals occurred at 4 and 3½ weeks respectively The soft tissue transplants recovered from animal 39 after its unexpected death showed clear signs of ante mortem devitalization Therefore although the twelve deaths represent a mortality of 20 % in the total series it was possible to include most of the material from these animals in the results

The remaining animals in the series were sacrified at intervals rang ing from 5 days to 16 weeks after operation In 4 cases (nos 10 11 12 13) the soft tissue specimens were removed by reoperation with sparing of the animal for later sacrifice and examination of the bone defects

During the earlier stages after transplantation the histological exa minations gave the greatest information Observations on the soft tissue transplantions are based exclusively on histological studies

II. *The fate of fresh embryonic bone implanted to muscular and subcutaneous beds*

In 27 animals embryonic bone was transplanted to the soft tissues, in 17 of them only to a subcutaneous bed and in 10 of them embryonic bone was in addition implanted into the pectoral muscles. The operative areas were examined after varying times from five days to 16 weeks. In 12 cases the observation time was 8 to 12 weeks and in 4 cases it was 12 weeks or longer. The average time lapse was 6 weeks.

The sequence of events and the final fate of the transplanted bone fragments were the same both in transplants to muscular and subcutaneous beds. There were no significant differences between transplanted embryonic bone fragments from embryos of different age of incubation.

Up to the end of the 1st week (animals 23, 24, 36) large areas of the implanted embryonic bone showed typical signs of devitalization such as empty lacunae and distorted and absent nuclei and hyperchromatic bone trabeculae. A microcellular reaction was already present around the implants.

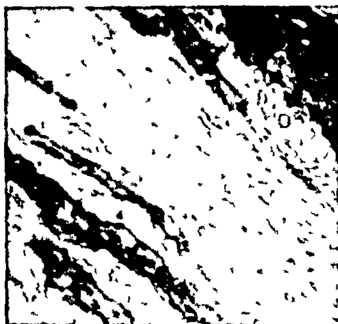


Fig. 1

Embryonic b[illegible] after transplantation to the subcutaneous tissue (animal no. 23). O[illegible] between the bone trabeculae. There is no micro[illegible] cellular infiltration [illegible] ×390



Fig 2

Embryonic bone two weeks after transplantation to the subcutaneous tissue (animal 34) There are apparently viable cells in the uppermost part of the trabeculae at the top of the picture whereas elsewhere the bone lacunae are empty indicating devitalization Haemotoxylin eosin × 390

In case no 23 the transplanted bone was devitalized 5 days after the operation However some osteoid tissue could be identified in apposition to the devitalized bone trabeculae (Fig 1)

At two weeks (animals 34 35 39) there was a lymphocytic reaction of varying intensity The majority of the fragments were clearly devitalized but in some sections there were still living cells in parts of the trabeculae (Fig 2)

At three weeks (animals 10 11 12 13 22 25) only disorganized eroded trabeculae could be found in the site of implantation (Fig 3)

These debris were strongly hyperchromatic There was still a prominent small cell reaction and a fibrous layer isolating the implant began to appear

In case no 10 21 days after the operation some osteoid tissue was also present in connection with the devitalized trabeculae limited to a small area

After that time it was often difficult to find the place of implantation



a



b

Fig. 3

Embryonic bone transplanted to the subcutaneous tissue ... 25 days after the operation. The transplant bone is completely devitalized. Hematoxylin-eosin. (a) × 100, (b) × 175.

either macroscopically or in sectioned specimens In the majority of cases there were only some traces of scar tissue in the area In only two animals (nos 11 and 16) could some remnants of the transplanted bone be found so long as 8 weeks after the operation and in another animal (19) there was some calcified debris within a mass of scar tissue 9 weeks after the operation The bone remnants were in these cases completely isolated from the surroundings by a well developed fibrous capsule

In summary embryonic bone of 12 14 16 or 18 days of incubation when transplanted into the muscle or the subcutaneous tissue of homogenous adult animals was soon devitalized A lymphocytic reaction developed around the transplants At later stages after transplantation the embryonic bone became completely disorganized and finally absorbed In the few cases in which some bone remnants could be identified at the site of the transplantation after 4 or more weeks these were isolated by a thick fibrous capsule No evidence was found of late osteogenesis from the transplanted bone nor from the host environment by an inductive action of the transplant In the two cases in which osteoid tissue was identified it was probably produced by the transplanted embryonic bone before its devitalization The fate of the transplanted bone was the same irrespective of whether one or more operative procedures were performed on the same animal Thus in the four animals in which embryonic bone was implanted only in the subcutaneous tissue the transplants in animals 23 and 24 were found devitalized 5 days and in animals 22 and 25 25 days after the operation Disappearance of the transplanted bone occurred more rapidly when transplanted to the muscles than when transplanted to the subcutaneous tissue

2) *Histological comparison of the embryonic bone and the autogenous bone filled trephine defects in the early stages of healing*

At the end of the first week (animals 1 36 37) the defects in the host bone filled with embryonic and autogenous bone material respectively were found filled with a callus composed principally of fibrous elements blood capillaries and the transplanted bone fragments An intense round cell infiltration was present in the case of embryonic and autogenous transplantations but it seemed to be somewhat more intense around the embryonic implants The transplanted autogenous bone fragments were in all cases well preserved within the callus mass and the majority of the trabeculae were devitalized The embryonic frag

ments were also well preserved within the callus. The young embryonic trabeculae in some areas were still viable but here also the great majority of the implanted trabeculae were dead. In some areas osteoid tissue confirmed by Azan stains was found within the callus in apposition to the embryonic trabeculae and seemed to be *arising from them*. The autogenous bone fragments were dead and there was no sign of osteogenetic activity surrounding them. Thus it appeared that some of the embryonic bone had preserved its vitality at this early postoperative stage. Some young bony trabeculae could be found arising from the periosteum of the host bone at the edge of the defect both in cases of embryonic and autogenous implantation.

At the end of the second week following operation (animals 2, 34, 3a) the fibrous consistency of the callus was more marked both in embryonic and autogenous transplantations. Almost no round cell reaction was *present in the autogenous callus whereas there was still a very intense* reaction around the embryonic bone transplants. Both embryonic and autogenous bone was devitalized in all cases and absorption of the transplants was well advanced so that only remnants of both embryonic and autogenous grafts were present within the respective defects. A regeneration of the periosteal layer of the host bone was present in this stage creeping towards and covering the callus on both its surfaces. Bone deposition of periosteal origin was seen on the surfaces of the callus. The development of the periosteal layer and the apposition of the young bone from it was more pronounced in the defects filled with autogenous grafts.

Thus in this stage of healing there was clear evidence that the embryonic bone had lost its viability. No osteogenetic activity was present within the callus of either the embryonic or the autogenous transplantations and a pronounced absorption of the grafts was observed. Bone healing was arising from the host periosteum and was more advanced in the case of the defects filled with autogenous bone.

By the end of the fourth week after operation (animals 3, 31, 32, 33) most of the transplants had been absorbed and only remnants of *both* embryonic and autogenous transplants were present within the respective defect and with no sign of osteogenic activity in the calluses. *Osteogenesis* arising from the host periosteum was very pronounced in the cases of the autogenous bone grafted defects while this was not so marked in the defects filled with embryonic bone.

By this stage the healing process of the defects by contribution from the margins of the defects was much more advanced in the case of

autogenous than in embryonic bone transplantation In both cases there was no appreciable osteogenic activity within the callus The transplanted embryonic and autogenous bone fragments were devitalized and most of them had already been absorbed

3) *Comparison of the embryonic and autogenous bone filled defects after 6 weeks or longer*

In most cases after about four weeks the differences in healing were obvious Even by gross examination one could assess the relative amount of bone filling the respective defects The assessment of the amount of bone by gross examination of the appearance hardness and architecture of the contents of the defects showed good correlation with the amount of bone demonstrated by subsequent contact microradiography Six weeks was arbitrarily chosen as sufficient time of healing to allow a final comparison of the bone healing process of the respective defects and contact microradiography was used to record objectively the differences in the areal narrowing of the defects by new bone There were 32 animals fulfilling the time requirement for this comparison (i e 6 weeks healing time) In 24 of these 32 animals there was a clear superiority of bony healing of the defects filled with autogenous bone as compared to the bone defects filled with homogeneous chick embryonic bone In the majority of cases the former defects were completely or nearly obliterated by bone bridging the trephine defects whereas the latter were filled by soft fibrous tissue or a very thin almost transparent connective tissue membrane The embryonic bone fragments had disappeared and any narrowing of these embryonic bone filled defects consisted of only a little peripheral constriction of the defects by new bone from the host

Figures 4 5 and 6 show examples of the contact microradiographic appearance of bone defects at 8 10 and 12 weeks respectively

In only three animals (4 6 28) was there a superiority of healing of the defect filled with fresh homogenous embryonic bone as compared to the control defect filled with autogenous bone

In four animals (5 12 20 29) there was insufficient difference in the relative healing to record a superiority of one defect over the other

4) *Observations regarding the animals with 4 bone defects*

Before it became clear that the embryonic bone was destroyed by the usual homograft reaction a study was begun employing 4 bone defects as described under methods and this concerns animals 6–17 inclusive



a

b

Fig. 4

Contact microradiograph of parts of sacrum fr... ter n ...) including the comparative bone defect 8 weeks after operation.
a) The defect filled with embryonic bone shows only slight marginal new bone formation.
b) The defect filled with autogenous bone chips almost completely obliterated by bone.

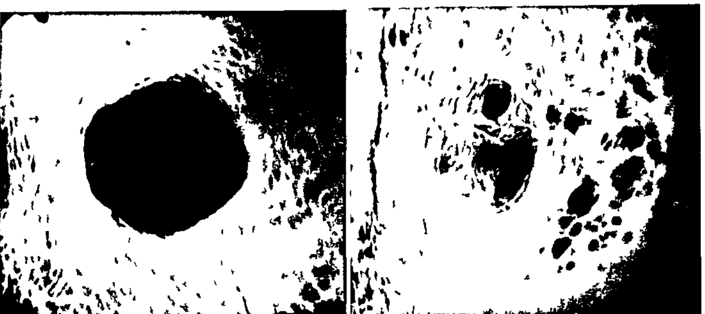


Fig 5

Contact micrcra liographs l arts of sacrum of rooster no 50 including the comparative bone defect 10 weeks after operation
a) he defect filled with chick embryonic bone shows no bony healing
b) The defect filled with autogenous bone chips is obliterated by bone except f r two small eccentrically placed residual defects



a *b*

Fig. 4

Contact microradiograph of parts of sacrum from patient no. 3 including the comparative bone defect 8 weeks after operation.

a) The defect filled with embryonic bone shows only slight marginal new bone formation.

b) The defect filled with autogenous bone chips is almost completely obliterated by bone.

TABLE 1

The Distribution of the Material

Animal no.	Transplantation: Soft tissue		Bony defect filled with				Age of embryonic bone (days)	Time of observation	Comparison of healing (8 wks or more)
	[illegible]	[illegible]	[illegible] (E)	[illegible] (A)	[illegible] (H)	[illegible] (O)			
1			×	×			12 d	1 wk.	
2			×	×			12 d	2 wks	
3			×	×			12 d	4 wks	
4			×	×			12 d	8 wks	E > A
5			×	×			12 d	16 wks	E = A
6			×	×	×	×	12 d	8 wks	E > A
7			×	×	×	×	12 d	11 wks	A > E
8			×	×	×	×	18 d	8 wks	A > E
9			×	×	×	×	16 d	8 wks	infected
10	×	×	×	×	×	×	16 d	4 wks	
11	×	×	×	×	×	×	16 d	8 wks	A > E
12	×	×	×	×	×	×	16 d	8 wks	A = E
13	×	×	×	×	×	×	16 d	3½ wks	
14			×	×	×	×	18 d	5 wks	
15			×	×	×	×	18 d	3 wks	
16	×	×	×	×	×	×	18 d	8 wks	A > E
17	×	×	×	×	×	×	18 d	8 wks	A > E
18	×	×	×	×			14 d	9 wks.	A > E
19	×	×	×	×			14 d	9 wks	A > E
20	×	×	×	×			14 d	9 wks	A = E
21	×	×	×	×			14 d	9 wks	A > E
22	×						12 d	25 days	
23	×						12 d	5 days	
24	×						12 d	5 days	
25	×						12 d	25 days	
26	×		×	×			12 d	14 wks	A > E
27			×	×			12 d	2 wks	
28	×		×	×			12 d	10 wks	E > A
29	×		×	×			12 d	12 wks	A = E
30	×		×	×			12 d	16 wks	A > E
31			×	×			12 d	4 wks	
32			×	×			12 d	4 wks	
33	×		×	×			12 d	4 wks	
34	×		×	×			12 d	2 wks.	
35	×		×	×			12 d	2 wks	
36	×		×	×			12 d	1 wk	

> = Superior healing

TABLE 1 (cont.)

Animal No.	Transplantation: Soft tissue		Transplantation: Bone defect filled with				Age of embryonic bone (days)	Time of sacrifice	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
3			x	x			12 d	1 wk	
38	x		x	x			12 d	6 wk	A > F
39	x			x			12 d	2 wks	
40	x			x			12 d	6 wks	A = F
41			x	x			12 d	16 wk	A > F
42			x	x			12 d	12 wks	A > F
43			x	x			12 d	16 wks	A > F
44			x	x			12 d	8½ wk	A > F
45			x	x			12 d	8½ wks	A > F
46			x	x			12 d	8½ wk	A > E
47			x				12 d	8½ wk	A > F
48			x	x			12 d	8 wk	A > F
49				x			12 d	10 wks	A > F
50			x	x			12 d	11 wks	A > F
51			x	x			12 d	6½ wks	A > F
52				x			12 d	8 wks	A > F
53	x		x	x			12 d	8 wks	A > E

(see table 1). This part of the study was then abandoned and only a few general observations can be made.

One bone defect was left empty in all of the cases in order to control the remote possibility that such a defect in the sacrum of a rooster might heal better when left vacant than when implanted with some sort of bone graft material. This showed that a full thickness trephine defect of 7mm in diameter usually fails to heal. An exceptional case was no. 12 and this animal exhibited such great innate bone healing power that it healed all 4 defects in eight weeks, including the one which was left empty.

The magnitude of the operative intervention using 4 defects and also soft tissue transplants in the same animal did not qualitatively affect the general pattern of superior healing of the defects filled with the autogenous bone as compared to those filled with the embryonic bone. The defects with autogenous bone showed better healing than all the other defects.

In these few animals in which preheated embryonic bone was im-

planted into one of the defects the impression was gained that the pre heated bone fragments were not disrupted and removed as rapidly as the fresh embryonic fragments They contributed equally little to the healing of the bone defects as did the fresh embryonic bone fragments No study was made of animal no 9 because of infection

DISCUSSION

The methods Regarding the part of the investigation dealing with the comparison of healing bone defects the reasons for placing the control defect in the same animal should be explained

The study is concerned with the healing of a bone defect by some local application in this case by homogenous embryonic bone Generally speaking one can expect any substance used as bone graft material to manifest its superiority locally and not through some central mechanism difficult to control Thus this is a problem of whether a local treatment of a bone defect produces more or faster bone healing of the defect than an identical control defect in the same animal filled with autogenous bone Autogenous bone is generally considered as the best currently available bone graft material (*Chase & Herndon* 1955) and it is used as a standard for comparison

By such a method one can disregard general factors affecting the bone healing of one animal as compared to another as for example the age the diet the general state of health and the inborn healing capacity In this connection there was observed a considerable variation in the bone reparative power of these animals This was particularly obvious in four animals that are recorded as showing insufficient difference between the healing of a defect and the control defect In one (no 5) both defects had healed so solidly after 16 weeks that no difference could be discerned In another (no 12) which had 4 trephine defects the animal s own bone reparative power was so great that it healed all defects in 8 weeks even the one that had been left empty On the other hand the other two animals (no 20 29) showed little or no healing of even the defects implanted with autogenous bone indicating the relatively low healing power of these hosts

It must however be noted that an inherent difficulty in this method of comparison is that it is possible for the superiority of a grafting material to be masked if it does operate through a central systemic mechanism Such a mechanism might of course accelerate the healing of the control defect too Germane to this discussion is the work investi

gating various so-called growth promoting substances on the healing of skin wounds. For example *Auerbach & Doljanski* (1944) found that the local application of embryonic and adult tissue extracts did not result in an acceleration of the healing of a treated experimental skin wound as compared to a control wound in the same animal. However further work using controls in other animals unmasked a wound accelerating affect that was hidden because it seemed to have operated also on the control wound in the same animal by some general pathway. This led them to investigate the effect of intraperitoneal injection of the tissue extracts on the rate of healing of experimental wounds (*Auerbach & Doljanski* 1945). They concluded that there was a significant accelerating affect agreeing with the results reported earlier by other authors (*Roulet* 1926, *Loria-Epstein* 1927, *Amoroso* 1931, *Sandelin & Bjorkesten* 1932).

These considerations evidently played no significant role in the investigation reported in this communication. If any systemic mechanism was operating either to accelerate or depress the healing of the bone defects, it certainly was not sufficient to obscure the considerable superiority of the autogenous bone which was obvious in the vast majority of cases. This superiority was clear even though the autogenous bone material contained considerable cortical fragments. To be the best possible autogenous graft for comparison the material probably should have consisted wholly of cancellous bone (*Siffert* 1955, *Nicoll* 1956).

The means of assessing the results. The main task of this investigation was to assess the ultimate contribution of the embryonic bone, if any, and by whatever mechanism, to the final healing of the experimental bone defects. This was gauged principally by contact microradiography after a healing time of six weeks or more. The choice of six weeks was purely arbitrary and actually the healing process seemed to be finished in most cases in four weeks and even less. Little difference was observed in the amount of new bone filling the defects from six to sixteen weeks following operation. Apparently the reparative process was exhausted and if a defect had not healed by six weeks there would be little if any further bony healing by sixteen weeks.

In a critique of the methods used to study the rate of healing of experimental wounds, the dangers of observations before the completed stage of healing are emphasized (*Young et al.* 1941). An initial acceleration produced by a substance in an early stage of healing might be nullified by a later retardation or lag phase in the healing.

Recent work on the acceleration of wound healing by cartilage exemplifies this difficulty (*Paulette & Prudden* 1959) An early acceleration of wound healing was observed but the continued presence of the cartilage in the wound actually delayed the eventual maturation of the scar

The embryonic bone transplants to the soft tissues and the calluses in the bone defects during the first few weeks of healing were studied by histological methods These studies were indispensable in establishing the fate of the embryonic bone particularly in the soft tissues but were much less helpful in comparing the healing of the respective bone defects Sections could be found to support almost any thesis and it is particularly difficult to be absolutely certain of the quantity and origin of the new bone

The fact that in most cases the soft tissue transplantation experiments and the implantation of the embryonic bone into the bony defects were done together in the same animals was of no significant importance in the fate of the embryonic bone nor on its affect on the healing of the bone defects Only four animals had soft tissue embryonic bone transplants uncomplicated by bone defect operations at the same time In these animals the embryonic bone was destroyed in just the same way as it was in the other animals when additional embryonic bone was implanted in the bone defects Many of the bone defect operations were performed with and without concomitant soft tissue embryonic bone transplantations and the overall results were the same

General discussion of the results It is well known that bones from the rapidly growing chick embryo can maintain their vigorous osteogenetic activity even in tissue culture with homogenous (*Fell* 1931–32) and heterogenous medium (*Miyagawa et al* 1957) Even the frontal bone of the chick embryo can subsequently show intense growth after having been stored at 4 C for eight days (*Judel* 1954) It is said that certain fetal cells when transplanted can overcome the normal homograft barrier (*Kay & Constandoulakis* 1959) but this evidently does not apply to chick embryonic bone from the twelfth day of incubation and thereafter This investigation shows that such bone cannot be expected to survive transplantation to adults of the same species Occasionally early new bone formation was found arising from the transplants and this agrees with other recent work on homogenous bone transplantation (*Chalmers* 1959)

Burke et al (1944) confirmed earlier work published in the immunological literature by showing that adult organs seem to be more distinct

antigenically as well as morphologically. However, *Schlechtman* (1948) and *Ebert* (1950) found organ antigens in the early chick blastoderm and it is possible that adult tissue antigens are present in the earliest stage of development or even in the unfertilized egg and that the concentration merely rises with development (*Tyler* 1955).

There has been a recent revival of interest on embryonic skin grafts partly due to the work of *Toolan* (1958). She showed that homogenous embryonic skin grafts could be maintained indefinitely on rabbits properly conditioned with cortisone but the only grafts retained by unconditioned hosts were derived from very young embryos in the first trimester of gestation. Commenting on Toolan's work *Medawar* (1959) points out that it seems hardly possible that the prolonged survival of the embryonic skin grafts is due merely to the absence of tissue antigens because even if they were absent to begin with they should have made their appearance when the embryonic skin underwent further differentiation on its host. *Goldstein & Laxter* (1958) found evidence of an immunological reaction even around very young embryonic skin homografts in human material. In much earlier work a real and obvious take of embryonic skin was observed for as long as six months after which the embryonic skin disappeared (*Gaillard & Koetermen* 1943). The difficulty of being certain of long term survivals is indicated by *Snyderman* (1955).

Although various experimental work supports the contention that the younger the embryo the less organ antigen is detectable the destruction of the embryonic bone used in this investigation was so outstanding that it is hardly likely that using very young embryonic bone (bone appears in the chick embryo at about the eight day of incubation) would produce results sufficiently different to warrant further investigation along the present lines, unless the host or the graft are modified in some way.

It has been suggested that the site of transplantation has a bearing on the fate of the graft (*Gaillard* 1953, *Greene* 1955). It was hoped that the rapid growth and establishment of the embryonic bone in the environment of the host's skeleton might allow it to withstand an eventual immunological attack. It is alleged that certain homografted tissues which are kept alive beyond a "critical period" are no longer susceptible to the immune response (*Woodruff* 1952). One might hope that the rapid growth of the embryonic bone in an environment perhaps partly protected from access by immunologically active cells could be decisive in enabling some of it to survive this critical period. No evi-

dence of the operation of such adaptive processes could be adduced from the present investigation Even relatively large amounts of embryonic bone implanted into the sacral defects of roosters were destroyed and removed

Bone formation by induction is a well known concept (*Levander* 1938 *Urist & McLean* 1953 *Heinen et al* 1949 *Ham & Harris* 1956 *Moss* 1958) and it needs no elaboration here Since *Carrel* (1913) demonstrated the potent activating power of extracts of chicken embryos on the growth of connective tissue in tissue culture the literature is replete with studies of the effect of embryonic and other tissue extracts on the healing of superficial wounds (*Kiaer* 1927 *Fischer* 1941–42 *Dann et al* 1941 *Hoffman & Dingwall* 1944 and others) It has been stated that there is almost unanimous agreement that embryonic extracts do accelerate the healing of wounds (*Needham* 1950) In this investigation the defects filled with homogenous embryonic bone and also those filled with autogenous bone material were healed by the ingrowth of the host bone and in almost every case this new bone was less in the defects filled with embryonic bone When similar defects were left empty (12 animals) there was little or no marginal healing except in no 12 which had an extraordinary regenerative capacity and healed the vacant defect as well as three other defects in which graft material had been implanted Those cases in which implantation of embryonic bone in the defect did result in a little more healing by the host bone than when nothing was implanted are hardly evidence of any bone growth stimulation or induction and in any case it is of no clinical importance in the light of the better performance of the autogenous material Therefore no significant growth promoting nor inductive affect on the host bone can be ascribed to the embryonic bone in the bone defects

Failing any other beneficial action of the embryonic bone one might expect that the smallness and delicacy of the embryonic bone fragments and their low mineral content might allow their more rapid substitution by ingrowth of the host bone than in the case of the autogenous fragments which contained some highly calcified cortical elements Even small fragments of cortical bone presumably present a greater obstacle to removal and substitution by the host bone This investigation showed that the bone defects healed principally from the margins Neither the embryonic nor the autogenous bone fragments contributed any significant osteogenesis Why then did not the defects filled with embryonic bone heal equally well as those filled with autogenous bone? One ex

plantation may be that the embryonic bone was destroyed too rapidly to act as an efficient scaffold for infiltration of the host bone. One might also consider that the host bone ingrowth was adversely affected by the immunological cellular reaction taking place although *Kelsall & Crabb* (1958) suggest that a lymphocytic reaction should stimulate rather than depress healing.

In the first operated animals histological and routine X-ray methods seemed to show superior healing taking place in the defects filled with embryonic bone. On this basis the potentialities of embryonic bone as grafting material were overestimated (*Cleland & Sevastikoglou* 1960). The continued investigation reported here has not confirmed these early interpretations.

SUMMARY AND CONCLUSIONS

The fate of embryonic bone on homogenous transplantation and its affect on the inherent normal reparative osteogenesis of the host has been studied by transplantation experiments of chick embryonic bone to 53 roosters.

Tibial bone fragments from chick embryos of twelve days incubation or more, when transplanted to the subcutaneous tissue or the pectoral muscles of roosters, did not survive more than a week or two. In most cases by four weeks the remnants had disappeared leaving little or no trace. Before the destruction of the transplantation material osteoid tissue was seen arising from some of the embryonic bone trabeculae. In no case was any late bone formation induced in the region of these transplantations when examined from two to four months after operation.

When the chick embryonic bone was implanted into full thickness trephine defects in the sacral bones of roosters, some of the embryonic fragments survived at least a week and they even gave rise to some osteoid tissue. Ultimately their fate was the same as with the transplantation *to soft tissues without any significant prolongation of survival*.

The bone defects filled with autogenous bone fragments healed better than those filled with embryonic bone.

No evidence was adduced of a beneficial effect by the embryonic bone on the reparative power of the host bone.

ACKNOWLEDGEMENTS

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RESUME

Le sort d un os embryonnaire dans une transplantation homogene et son effet sur l osteogenese de réparation normale naturelle chez l hote ont ete étudies par des experiences de transplantation d os embryonnaire de poussin sur 53 coqs

Des fragments d os tibial d embryon de poussin apres 12 jours d incubation ou plus ne survivent pas plus d une semaine ou deux lorsqu ils sont transplantés dans le tissue sous cutané des muscles pectoraux des coqs Dans la plupart des cas au bout de quatre semaines les restes avaient disparu laissant une faible trace ou pas de trace du tout Avant la destruction de la transplantation on a pu voir un tissue osteoide se developper de certains des trabecules de l os embryonnaire Dans aucun cas il ne s est produit de formation osseuse tardive dans la region de ces transplantations examinees entre deux et quatre mois apres l operation

Lorsque le tissue embryonnaire de poussin a eté implanté dans toute l épaisseur de defectuosites de l os du sacrum chez les coqs certains des fragments embryonnaires survecurent au moins une semaine et donnerent lieu a l apparition d un peu de tissu osteoide Finalement leur sort a cependant ete le meme que dans les transplantations sur tissu mou sans aucune prolongation de vie notoire

Les defectuosités osseuses remplies de fragments d os autogene guerissent mieux que celles remplies d os embryonnaire

Il n apparait pas que l os embryonnaire ait un pouvoir reparateur avantageux sur l os de son hote

ZUSAMMENFASSUNG

Das Schicksal von Embryoknochen nach homogener Transplantation und seine Wirkung auf die angeborene normale reparative Osteogenese des Wirtes wurde mittels Transplantationsversuchen von embryonalem Hühnerknochen auf 63 Hähne untersucht. Knochenstückchen der Tibia von Hühnerembrios die 12 oder mehrere Tage bebrütet worden waren, überlebten nicht mehr als ein oder zwei Wochen, wenn sie in das subkutane Gewebe oder den m. pectoralis von Hähnen verpflanzt wurden. In den meisten Fällen waren die Reste nach 4 Wochen verschwunden unter Hinterlassung von geringen oder keinerlei Spuren. Vor der Zerstörung des Transplantationsmaterials konnte in einigen Fällen osteoides Gewebe, das von den embryonalen Knochentrabekeln ausging, beobachtet werden. In keinem Falle war irgendwelche späte Knochenbildung hervorgerufen worden, wenn man zwei bis vier Monate nach der Operation untersuchte.

Wenn der embryonale Hühnerknochen in durchgehende Trepanationsdefekte des Kreuzbeines von Hähnen eingepflanzt wurde, überlebten einige der embryonalen Fragmente zumindest eine Woche und es bildete sich von ihnen aus etwas osteoides Gewebe. Aber schliesslich war ihr Schicksal gleich dasselbe als jener, die in Weichteilgewebe verpflanzt worden waren, ohne irgendwelche Verlängerung des Überlebens von Bedeutung.

Die Knochendefekte, welche mit autogenem Knochen ausgefüllt wurden, heilten besser als die mit embryonalen Knochen.

Keinerlei Beweis einer günstigen Wirkung des embryonalen Knochens auf die Wiederherstellungskraft des Wirtsknochens konnte nachgewiesen werden.

REFERENCES

Amorosi, O.: Succi embrionali e rigenerazione. Riv. di Sper., 33: 1931.

Auerbach, F., & Doljanski, L.: The effect of cell growth-promoting tissue extracts on the healing of experimental cutaneous wounds in rats. I. Local application. Brit. J. Exptl. Path., 25: 38, 1944.

Auerbach, F., & Doljanski, L.: Effect of cell growth-activating tissue extract parenterally applied on experimental wounds. Proc. Soc. Exptl. Biol. Med., 58: 11, 1945.

Bert, P.: De la greffe animale. Paris, 1863, quoted by Caillard, 1953.

Bosaeus, W.: Beiträge zur Kenntnis der Gene der Ovarialembryone. Almquist & Wiksells AB, Uppsala, 1926.

Burke, V., Sullivan, N. P., Petersen, H., & Weed, R.: Ontogenetic change in antigenetic specificity of the organs of the chick. J. Infect. Dis., 74: [illegible], 1944.

Carrel A Artificial activation of the growth in vitro of connective tissue J Exptl Med., *17* 14 1913

Chalmers J Transplantation immunity in bone grafting J Bone & Joint Surg *41 B* 160 1959

Chase S W & Herndon C H The fate of autogenous and homogenous bone grafts (A historical review) J Bone & Joint Surg *37 A* 809 1955

Cleland H N & Sebastikoglou J A Experimental studies of embryonic bone trans plantation Preliminary report Bull Soc Intern Chir *19* 641 1960

Dann L Gluckmann A & Tansley K The healing of experimental wounds with epicutan Brit J Exptl Path *27* 70 1941

Dempster W J An introduction to experimental surgical studies C C. Thomas Baltimore 1957

Ebert J D An analysis of the effects of anti organ sera on the development in vitro of the early chick blastoderm J Exptl Zool *115* 351 1950

Fell H B The osteogenetic capacity in vitro of periosteum and endosteum isolated from the limb skeleton of fowl embryos and young chicks J Anat *66* 157 1931/32

Fischer A The nature of growth promoting substances in embryonic tissues Acta Physiol Scandinav *3* 54 1941/42

Gaillard P J & Kooreman Hand Ned Nat en Geneesk XXIX Congr p 42 1943 quoted by Gaillard 1953

Gaillard P J Growth and differentiation of explanted tissues in International Review of Cytology vol II p 331 Academic Press Inc New York 1953

Goldstein M & Baxter H Fetal tissue homografts Annals of N Y Acad Sci *73* 564 19 8

Greene H S N Compatibility and noncompatibility Ann Acad Sci., *59* 311 1955

Ham A W & Harris W R Repair and transplantation of bone in Biochemistry and Physiology of Bone Ed., Bourne G H Acad Press Inc., New York 1956

Heinen J H Jr Dabbs G H & Mason H A The experimental production of ec topic cartilage and bone in the muscles of rabbits J Bone & Joint Surg., *31 A* 765 1949

Hoffman R S & Dingwall J A An experimental and clinical study on the use of adult tissues extract in the acceleration of wound healing Surgery 79 103 1944

Judet J & Judet R Banque d os Rev d Orthop., *40* 403 1954

Kay H F M & Constandoulakis M A foetal tissue bank Problems and prospects B M.J., p 575 Feb 28 1959

Kelsall M A & Crabb F D Lymphocytes and plasmocytes in nucleoprotein meta bolism Ann N Y Acad Sci., *72* 293 1958

Kiaer S Biologische Beobachtung uber Wunderlung Arch klin chir., *149* 146 1927

Levand r C A study of bone regeneration Surg Gyn & Obst., *67* 70 1938

Lorin Epstein M J Ueber einige allgemeine Faktoren der Wiederherstellungspro zes e und ihre Bedeutung fur die chirurgi che Pathologie Arch f klin chir., *144* 632 19 7

Medawar P B Iso antigens in Biolog cal Problems of Grafting Ed., Albert F., Université de Liege 19 9

ZUSAMMENFASSUNG

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REFERENCES

Amprino, O.: Succi embrionari e rigenerazione. Riv. de Sper. 7: 33, 1931.

Auerbach, E. & Doljanski, L.: The effect of cell growth promoting tissue extracts on the healing of experimental cutaneous wounds in rats. I. Local application. Br. J. Exptl. Path. 1?: 5-38, 1944.

Auerbach, E. & Doljanski, L.: Effect of cell growth activating tissue extracts parenterally applied on experimental wounds. Proc. Soc. Exptl. Biol. Med. 58: 11, 1945.

Bert, P.: De la greffe animale. Paris 1863, quoted by Caillard 1953.

Borghese, W.: Beiträge zur Kenntnis der Genese der Ovarialembryome. Almqvist & Wiksells AB, Uppsala [illegible].

Burke, V., Sullivan, N. P., Petersen, H. & Weed, R.: Ontogenetic change in antigenetic specificity of the organs of the chick. J. Infect. Dis. 74: 225, 1944.

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MECHANICAL ANALYSIS OF FORCES INVOLVED IN IDIOPATHIC SCOLIOSIS

By

OLOV LINDAHL and ESKIL RAEDER[1]

As early as 1824 *Bamfield* (1) noted that there was a definite relationship between bodily growth and the progress of scoliosis, an observation that has since been confirmed by a number of workers (2, 5, 8, 13, 14) and presented in orthopaedic textbooks (7, 9, 12).

It is generally agreed that in scoliosis the lateral curvature of the column is always accompanied at an early stage by a characteristic rotation of the vertebrae. Unless this rotation is extremely small there will be structural changes in, and deformation of, individual vertebrae and especially of ligaments and discs.

On the basis of these three phenomena—progress with growth, lateral curvature and rotation—an analysis of the mechanical forces probably involved in the development of scoliosis was performed.

The movements executed by the column can be divided into normal physiologic ones (referred to below as *acute* movements) and slow progressive ones associated with structural changes occurring in disease and deformative processes (referred to as *chronic* movements). The acute movement is characterized by the fact that it occurs suddenly and may range in extent between the limits permitted by the skeleton, articular ligaments and muscles. The chronic movement takes place over months or years, and is practically irreversible.

Both acute and chronic movements of the column can be assumed to follow mechanical laws.

The range of the acute movement of the column has been carefully analyzed. In pure flexion and extension movements there is no intervertebral rotation. In lateral bending there is, according to some workers (11), a rotation, but this, if it does in fact occur, is insigni-

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ficant compared with the rotation in scoliosis. In full turning of the trunk there is a certain rotation between adjacent vertebrae—in isolated specimens one degree for the lumbar and 3–4° for the thoracic spine. The deformation in scoliosis cannot be produced by acute movement of the spine.

The rotation in scoliosis consists of rotation of the vertebral bodies towards the convexity. The rotation of a particular vertebra can be measured with reference to, for instance, the pelvis or the subjacent vertebra, and the direction of motion will depend on which reference point is chosen. If the pelvis is taken as the reference, the rotation of every vertebral body in the primary curve will occur in the same direction, say clockwise with the patient erect. If the vertebra subjacent to the vertebra in question is taken as the reference, the rotation will be clockwise for the upper half of the curve and anticlockwise for the lower half. This difference is not always recognized—for example in connection with the theory that the rotation in scoliosis may be due to disturbance of the short rotators on one side (16). These muscles act

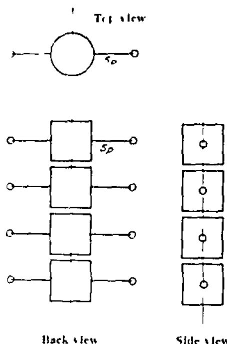


Fig. 1 A.
Model of a column consisting of four cylinders with spacer (sp) and connected so as to be flexible in all directions.

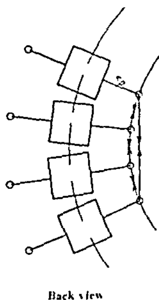


Fig. 1 B.
Lateral flexion of the column in Fig. 1 A.

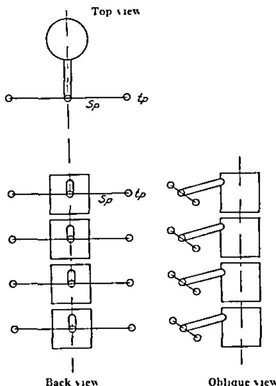


Fig 2 4
Model of a column similar to that in Fig 1 except that the spacers *sp* are situated in a plane behind the column to which they are joined by rods

in the same direction throughout the column and therefore cannot give rise to such a scoliotic rotation

From the mechanical standpoint the spinal column can be regarded as consisting of two components one column composed of the vertebral bodies and another composed of the arches and processes This distinction between these two components is also valid on developmental grounds for the growth of the vertebral body column which must be *regarded as having a locomotoric function follows the growth of the* extremities whereas the arch column which may be considered as a protective sheath for the cord develops in step with the cranium (10)

If these two components of the spinal column are separated by sawing them apart it is found that the arch column can be bent to almost any extent in any direction whereas the vertebral body column is considerably less flexible and is therefore the one that mostly limits

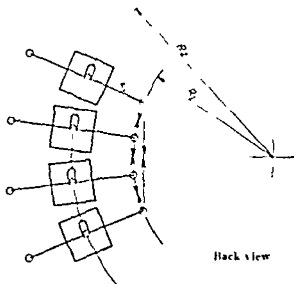


Fig. 2 B
Lateral flexion of the column with rotation prevented. R_1 radius of curvature of line through the tie point Ip. R radius of curvature of the column axis.

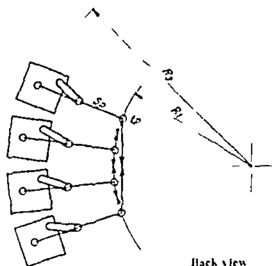


Fig. 2 C
Lateral flexion of the column with rotation permitted. R_3 radius of curvature of the axis of the column. $R_3 > R$

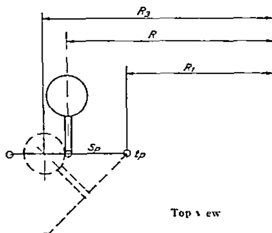


Fig 2 D
Top view of middle vertebra during lateral flexion without and with rotation of the column

the flexibility of the spinal column (6) This distinction between the two components is essential to the following discussion The vertebral body column is the structure that offers the greater resistance to forces acting on the column and tending to deform it and it will therefore be the less deformed other conditions being equal

Consider the model illustrated in Fig 1 A which represents very approximately the spinal column This can be bent in various directions When the distance between the spacers (*sp*) is reduced on one side there is a lateral flexion without rotation (Fig 1 B) The movement will be largely the same whether the shortening occurs between adjacent pairs of spacers or only between the top and bottom ones The same flexion is obtained if instead of the distance between the spacers being shortened the column is lengthened and the distance between the spacers on one side is kept constant

The model in Fig 2 A is a closer mechanical representation of the spinal column Here the movements will be quite different The tie points (*tp*) are situated in a plane on the side of and behind the actual vertebral body column If it is supposed that the column presents an elastic resistance to any change in shape then any decrease in the distance between the tie points (*tp*) will give rise to a rotation as well as to a lateral flexion The same movements will occur by elongating the vertebral column while keeping the distance between the tie points constant on one side Mechanically this rotation is due to the fact that

a lateral flexion results in a more pronounced curvature of the model if there is no rotation (Figs 2 B and D) than if there is a rotation (Figs 2 C and D) For the radius of curvature in the former case will be smaller (R) than in the latter (R_3) and the model will therefore assume the position that under the prevailing conditions will involve the least deformation If the uppermost and lowermost components of the model in such a bending experiment can rotate freely all the segments (the vertebrae) will rotate by the same amount and in the same direction in relation to a reference point outside the system If on the other hand the uppermost and lowermost parts of the model can rotate only a small amount and there is some resistance to intersegmental rotation the maximum rotation will be a maximum at the centre of the

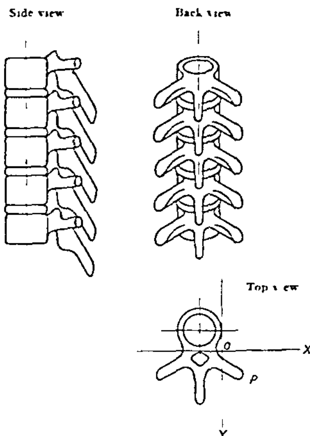


Fig 3 4
More representative model of the spinal column YOX quadrant where the binding forces between the transverse processes tend to produce both lateral flexion and rotation.

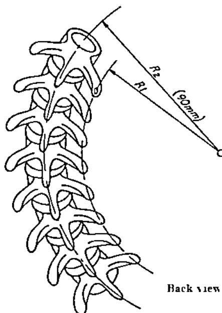


Fig 3 *B*

Lateral flexion of the column in Fig 3 A rotation is prevented R_1 radius of curvature of a line through the tips of the transverse processes R radius of curvature of the axis of the vertebral column (90 mm)

curve and will decrease with distance above and below this point In other words we obtain the deformation typical of scoliosis

In the model in Fig 3 A which mechanically is a closer approach to the spinal column the tie points correspond to the tips of the transverse processes Here too it is seen that a pure lateral flexion unaccompanied by rotation (Fig 3 B) involves a more pronounced curvature of the vertebral body column than if rotation is permitted (Fig 3 C) In the model under consideration the radius in the former case will be 90 mm and in the latter 100 mm (Fig 3 D) If it is supposed that the column presents an elastic resistance to bending a decrease in the distance between the transverse processes will give rise to forces such that the spinal column will tend to be deformed in a manner typical of scoliosis From the mechanical aspect it is immaterial whether there is an absolute reduction in the distance between the transverse processes (as for instance in pathologic shrinkage) or whether the reduction is relative (growth of the vertebral body column with a constant distance between the transverse processes)

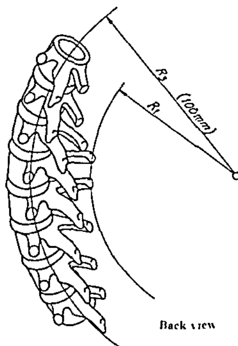


Fig 3 C

Lateral flexion of the column in Fig 3 A rotation of the vertebral bodies is permitted R_1 radius of curvature of the line through the tips of the transverse processes (same as in Fig 3 B) R_3 radius of curvature of the axis of the vertebral column (100 mm and greater than in Fig 3 B where rotation was prevented)

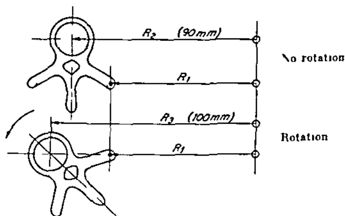


Fig 3 D

Top view of the middle vertebra of the model in Fig 3 A during lateral flexion without and with rotation

Acute movements of the human column do not permit such a deformation but it may be supposed that under the influence of the forces discussed above the shape of the structural parts of the spinal column gradually change in shape so that they assume the form and position that involve the minimum deformation of the vertebral body column

Under what conditions can such forces act in the spinal column? It has already been noted that the scoliotic rotation occurs during growth of the vertebral column There need then be no absolute reduction in the distance between the points (*tp*) or the tips of the transverse processes If there were forces acting unilaterally between these processes that prevented them from separating with the growth of the vertebral body column the same situation would arise as that discussed above Between the transverse processes there are fairly strong intertransverse ligaments and short and rather weak intertransverse muscles If on one side these structures did not grow at the same rate as the rest of the spinal column a typical scoliosis with rotation would result

Though various models can be designed where the application of appropriate forces at the appropriate points will produce a similar deformation such models do not provide a convincing solution of the problem consistent with the anatomy of the spinal column A mechanical analysis however suggests that the deformity in idiopathic scoliosis is caused by restraining forces acting between the tips of the transverse processes on one side such forces are exerted by the intertransverse ligaments or muscles

The connection between the progress of scoliosis and growth has given rise to the theory that the deformity in scoliosis is due to a difference in vertical growth of each side of the vertebrae but this is not a convincing explanation for though such a discrepancy could account for a lateral flexion in one plane it could not cause a rotation this would require tensile or binding forces behind and on one side of the vertebral column

The only anatomic structures in the spinal column that are situated in this quadrant (XOY) are the transverse processes (Fig 3 A) Outside the spinal column this quadrant contains the posterior extent of the ribs and certain long dorsal muscles Restriction of the vertical growth of these structures on one side also offers a possible mechanical explanation of the deformity in scoliosis

If supporting the primary cause of the scoliosis to lie in unilateral disturbance of vertebral growth or in disturbance in the disc account

is taken also of the forces acting on the intratransverse ligaments these forces would give rise to a rotation of the vertebral bodies towards the side opposite to that on which it actually occurs

No satisfactory explanation of the rotational deformation seems to have been presented in orthopaedic literature *Risser* (15) has compared the column to a rubber tube which after being partially severed from the front and behind is bent laterally If the incisions are not equally deep there will be a rotation like displacement between the two parts of the tube While this is an instructive illustration of simple mechanical laws it cannot be regarded as explaining the rotation in scoliosis *Tidestrom* (17) has suggested a similar mechanical explanation of the rotation using a model of the spinal column where the vertebrae were connected by Polhem couplings which permit motion only in two perpendicular planes On bending such a model laterally there will therefore be a forced rotation This too provides no explanation of the rotation in scoliosis since the vertebrae are not linked in this manner

Has then the mechanical explanation here presented any therapeutic application? If at an early stage of the development of scoliosis the binding forces between the transverse processes are removed on the concave side of the curve the progress of the scoliosis would be arrested As *Cobb* (2 4) has pointed out we do not know if a case of scoliosis will progress at a given moment A stationary condition after an operation of the kind implied could not therefore be regarded as proof that the operation had any therapeutic effect It would be necessary to study a large series of cases with comparison between treated and untreated subjects before the value of the operation could be assessed

It is also possible that removal of the binding forces on the concave side might be of direct therapeutic value in that it would permit gradual *regression of the scoliosis Though possible such an effect* is not necessary on mechanical grounds *Wenger*s study of the incidence of scoliosis after thoracoplasty provides support for such a mechanism (18 19) he showed that the factor that was most frequently responsible *for postoperative scoliosis was the resection not of the ribs* but of several transverse processes Scoliosis with rotational deformation was regularly observed after resection of several processes and the severity of the condition then depended on the number of processes resected The convexity appeared on the side of resection The occurrence of scoliosis was essentially independent of the age of the patient and even elderly persons were afflicted The mechanical explanation of this scoliosis is approximately the same as for the models discussed The trans

verse processes and the connecting ligaments can be regarded as ties corresponding to the lateral stays on a mast. The processes then function as cross trees or spacers. If several processes are resected the continuity of the stay is interrupted, the dynamic balance in the spinal column will then be disturbed and the column will be subjected to largely the same forces as those discussed above. This explanation applies to an initially straight column.

If the column is already scoliotic a different situation is presented and the weight of the body then tends to retain or to increase the deformation. Removal of the restraining forces on the concave side would arrest the progress of the condition and even render possible a regression. On the other hand, it is not certain that the excess dynamic force created on the convex side would suffice to bring the column back to its normal form, and even if it did, this process would probably take at least as long as the development of scoliosis, since a normalization of the shape of the vertebral bodies, ligaments and discs would be necessary.

On the basis of these mechanical principles between four and seven transverse processes were removed on the concave side in cases of idiopathic scoliosis in an attempt to arrest the progress and possibly to effect an improvement. The patients were from 11 to 17 years old. The scoliosis had been progressing continuously and the angle at operation ranged from 65 to 114. The results of these seven operations were encouraging but no definite conclusion could be drawn after only 3–6 months. They will be published in due course.

SUMMARY

A mechanical analysis was performed of the forces involved in the development of idiopathic scoliosis. The findings suggest that scoliosis is due to restriction of the growth of the intertransverse ligaments or muscles on one side. If this is in fact the case, the progress of the deformity could probably be arrested and even an improvement be procured by removal of one or more transverse processes on the concave side.

RÉSUMÉ

Il a été procédé à une analyse mécanique des forces impliquées dans le développement de la scoliose idiopathique. Les trouvailles font

penser que la scoliose est due à une restriction de la croissance des ligaments ou des muscles intertransversaire d'un côté. Si c'est le cas, le progrès de la déformité pourrait probablement être arrêté et on pourrait même obtenir une amélioration par la résection d'un ou plusieurs apophyses transverses du côté concave.

ZUSAMMENFASSUNG

Eine mechanische Analyse der Kräfte, die bei der Entwicklung der idiopathischen Skoliose eine Rolle spielen, wurde ausgeführt. Die Befunde legen es nahe, dass die Skoliose infolge einer Einschränkung des Wachstumes der intertransversalen Ligamente und Muskeln auf einer Seite entsteht. Wenn sich das tatsächlich so verhalten sollte, dann könnte das Fortschreiten der Deformität wahrscheinlich aufgehalten, ja selbst eine Besserung hervorgerufen werden, wenn man einen oder mehrere processus transversi auf der konkaven Seite entfernt.

REFERENCES

1. *Bonfield*: cited by Risser J. 14.
2. *Cobb J.*: J. Bone & Joint Surg. *40A*, 507–510, 1958.
3. *Cobb J.*: Bull. Hosp. Joint Dis. *19*, 187–209, 1958.
4. *Cobb J.*: J. Bone & Joint Surg. *42A*, 1413–1425, 1960.
5. *De Forest A.*: J. Bone & Joint Surg. *40A*, 505–507, 1958.
6. *Fick R.*: Handbuch der Anatomie und Mechanik der Gelenke. Part 3. Gustav Fischer, Jena 1911, pp. 69–99.
7. *Goldstein L.*: The surgical treatment of scoliosis. Charles C. Thomas, Illinois 1959.
8. *Hibbs R., Risser J. & Ferguson A.*: J. Bone & Joint Surg. *29*, 91–104, 1931.
9. *Kleinberg S.*: Scoliosis. The Williams & Wilkins Company, Baltimore 1951.
10. *Knutsson F.*: Acta radiol. *55*, 401–408, 1961.
11. *Lovett R. W.*: Lateral Curvature of the Spine and Round Shoulders. 5th ed. Edited by F. Ober and A. Brewster. Blakiston Company, Philadelphia 1931.
12. *Lindemann K.*: Ätiologie und Pathogenese der Skoliose. Handbuch der Orthopädie. G. Hohmann, M. Hackenbroch & K. Lindemann. Georg Thieme, Stuttgart 1958, vol. II, pp. 160–187.
13. *Ponseti I.*: Bull. Hosp. Joint Dis. *19*, 216–224, 1958.
14. *Risser J.*: Bull. Hosp. Joint Dis. *19*, 166–186, 1958.
15. *Risser J.*: cited by Lindemann 12.
16. *Roaf R.*: J. Bone & Joint Surg. *40B*, 312–332, 1958.
17. *Tideström F.*: Nord. Med. *60*, 967, 1958.
18. *Wenger L.*: Arch. Surg. *44*, 119–128, 1942.
19. *Wenger L. & Herman M.*: Quart. Bull. Sea View Hosp. *7*, 45–55, 1941.

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IDIOPATHIC SCOLIOSIS A PRELIMINARY REPORT

By

OLOF PEREY and TORE RYDMAN

Many afflicted with structural scoliosis will usually become deformed to a high degree and also become a chronic invalid For this reason doctors had an early interest in the disease but systematic studies have been made only in this century For adequate treatment knowledge of the aetiology is necessary *Cobb* has suggested a useful aetiological classification of the structural scoliosis in 5 main groups Four of these groups have a clear pathogenesis but the 5th is not associated with any other pathological condition and is therefore diagnosed by process of exclusion This is idiopathic scoliosis

Idiopathic scoliosis does not appear in animals and it is therefore impossible through animal experimentation to achieve an understanding of the cause and it is as difficult to test different forms of treatment *Langenskjold & Michelsson* have experimentally produced progressive scoliosis in rabbits through unilateral resection of the posterior ends of the 6th to 11th ribs including the costal parts of both costo vertebral joints They also produce a prominent rotation of the vertebrae

Slight scoliosis has also been produced in animals in other ways excision or denervation of muscles (*Schwartzmann & Miles* 1945) operations on growth zones of vertebrae (*Haas* 1939 *Bisgard & Mussalmа* 1940 *Nachlas & Borden* 1951)

In order to produce scoliosis in animals a considerable interference in normal anatomy has to be made and the clinical interpretation of the progress is difficult

Another way to clarify the mechanism of production of the disease is to study the disease processes in patients Several different avenues and ideas have been followed *James* (1952 1954 1959) has by follow up studies of a large number of patients during long periods reported the prognosis and results of treatment He also made a post mortem

examination on a spine in an 11 months old child, who for 8 months had a progressive scoliosis The vertebral column showed rotation without congenital anomalies Microscopic examination of the vertebral epiphyses showed a normal histological pattern

Farkas (1954) is of the opinion that the differences in the oblique position of the intervertebral joints causes a more pronounced rotation on lateral flexion The epiphyseal ring is the weakest part of the vertebral column Before its closure it is very loosely attached at its periphery Slipping of the Epiphyseal Ring on the Body is preceded by a number of phenomena which together constitute the predisposing causes of idiopathic scoliosis According to *Farkas* this predisposition coupled with the mechanical factor of weightbearing brings about the scoliosis deformity

McCarroll & Costen (1960) investigated the epiphyseal rings of the vertebral body in 4 operated cases They found such pronounced changes that they considered this may help to explain the aetiology of the idiopathic scoliosis

Truela (1957) reports disturbances in the blood flow to the epiphyseal rings This may cause either excessive or diminished rate of growth as well as the opposite or a permanent cessation of growth

The metabolism of scoliotic children has been investigated by *Stearns Jo Yun Chen & McKinley* (1955) They found no change in the mineralization but a definite change in protein metabolism

As seen from the above the different investigations have not given conclusive evidence nor homogeneous results Several authors speak about a disposition connected with other factors *Murdock* (1959) describes cases of uniovular twins who both had right convex scoliosis between Th 5–11 at 46 and 55 respectively According to him this could well be due to an hereditary factor

PERSONAL INVESTIGATIONS

The developmental history of the vertebral column is complex and the vertebrae and the discs cannot be dissociated from each other In their structure and function the discs and vertebrae likewise must be recognized as two elements of one unit The notocord is the forerunner of the vertebral column and though all trace of the notochord is normally lost within the vertebral bodies it is intimately concerned with the formation of the intervertebral discs The intervertebral disc has the most complex development of all the joints largely because of the



Fig 1

Case K S Discography in L_2–L_4 It is a curve of 15 L_3 and L_4 have the nucleus in centre L has the nuclues extremely to the concave side

notochord within the primitive disc The end result is that the peripheral part of the primitive disc forms the annulus fibrosus whereas the central part with the notochord forms the nucleus pulposus

The long developmental chain to the final vertebral spine presents several possibilities for different anomalies It is not unusual that the notochord causes an anomaly two discs may hang together through a canal in the vertebral body The canal may have a horse shoe shape with a forward concavity There is thus the possibility of the nucleus being developed asymmetrically in the disc An eccentric nucleus must result in an abnormal movement between vertebral bodies and may cause both lateral curvature as well as rotation



Fig 2

Case Y A Scolios curve of 18 The disc between L -L3 is examined
The nucleus is laterally situated to the convex side

In order to find out if this reasoning has a background of reality three patients with idiopathic scoliosis were examined by discography as per *Lindblom* (1947) A criticism of this method of investigation is that it may be dangerous on the grounds that the injection canal may provide an outlet for disc herniation *Pease* (1935) This has not been found either at microscopy two months after discography (*Perey* 1951) or at mechanical investigations *Friberg* (1941) *Perey* (1957)

The 3 patients were thoroughly examined before discography to try to exclude any already known aetiology for the scoliosis EMG for instance was performed both on the erector spinae as well as on the

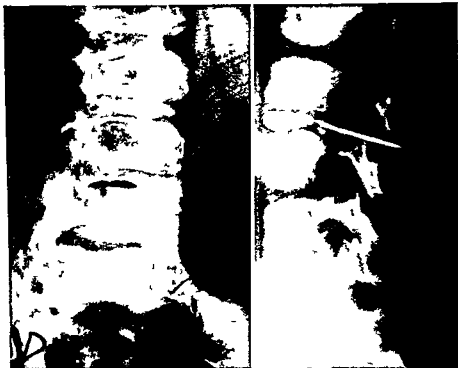


Fig 3

Case I D Discography of L_3 The curve was 15 when the scolioses was discovered The nucleus is dislocated laterally to the convex side On L and S_1 there is a spina bifida

abdominal musculature The 3 children (K S 14 years Y A 12 years and I D 2 years old) had recently detected scoliosis The two older ones were examined every year by the school physician and we are of the opinion that the scoliosis developed during the last year It may thus be concluded that the findings are not secondary to the scoliosis

Discography showed that in the apex of the scoliotic curve the nucleus was not situated centrally in the disc In two cases it was dislocated laterally on the convex side in one case (K S) very far on the concave side In the other discs examined the nucleus was centrally placed in the disc

It is to be noted in all three cases examined that the nucleus was located asymmetrically in the disc at the apex of the curve It seems more natural that the nucleus should be on the convex side which it is in two cases In the case in which the nucleus lies on the concave side it

is so much dislocated that the outer wall has to be formed by a very thin annulus. That the nucleus in fact is situated so far laterally as seen from the picture is proven by biplane pictures as well as by rotation of the patient at screening.

It is of interest to note that both in the 2 year old and in the 12 year old patients there are lateral ruptures in the discs examined. Ruptures that can be filled with contrast medium are considered a degenerative change caused by age and which seldom appear before the age of 20. Ruptures in the discs of these children are additional evidence for a primarily abnormal disc.

These 3 cases are too few to constitute evidence but they give rise to a supposition of a congenital anomaly contributing to a lateral curvature and a rotation which later can be accelerated by other factors such as straining of the musculature *Roaf* (1958) and changes of the epiphyses.

In older cases which have been operated on *Roaf* has observed that the nucleus pulposus was very near the lateral border of the disc. In these cases it is impossible to judge if the dislocation of the nucleus is primary or secondary.

SUMMARY

Three cases of very early idiopathic scolioses were examined by discography. At the apex of the scoliotic curve the nucleus pulposus was dislocated laterally and this finding suggested a congenital anomaly contributing to a lateral curvature.

RESUME

Trois cas de scolioses idiopathiques tres precoces ont ete examinees par discographie. Au sommet de la courbe scoliotique le noyau spongieux était disloque lateralement et cette trouvaille fait supposer la *présence d une anomalie congénitale contribuant à la flexion latérale*.

ZUSAMMENFASSUNG

Drei Falle von sehr fruhzeitiger idiopathischer Skoliose wurden mittels Diskographie untersucht. Am Scheitel der skoliotischen Kurve war der nucleus pulposus nach lateral disloziert und dieser Befund legt den Gedanken einer angeborenen Anomalie nahe, die zur lateralen Krummung beiträgt.

REFERENCES

Bisgard J D & Musselman M M Scoliosis Its experimental Production and Growth Correction Growth and Fusion of Vertebral Bodies Surg Gynec and Obstet 70 1029 1940

Cobb J R Outline for the Study of Scoliosis Am Acad of Orthop Surg Instructional Course Lectures Vol 5 p 261

Farkas A J The Pathogenesis of Idiopathic Scoliosis J Bone and Joint Surg 36B 617 1954

Friberg S Low back and sciatic pain caused by intervertebral disc herniation Acta Chir Scandinav Suppl 64 1941

Haas S L Experimental Production of Scoliosis J Bone and Joint Surg 21 963 1939

James J I P & Pilcher M F Infantile Structural Scoliosis J Bone and Joint Surg 41B 719 1959

James J I P Idiopathic Scoliosis Prognosis Diagnosis and Operative Indication Related to Curve Pattern and Age of Onset J Bone and Joint Surg 34B 514 1952

James J I P Idiopathic Scoliosis J Bone and Joint Surg 36B 36 1954

Langenskiöld A & Michelson J E Experimental Progressive Scoliosis in the Rabbit J Bone and Joint Surg 43B 116 1961

Lindblom K Diagnostic Puncture of Intervertebral discs in sciatica Acta Orthopaed Scandinav 17 231 1947

McCarroll H R & Costen W Attempted Treatment of Scoliosis by Unilateral Vertebral Epiphysial Arrest J of Bone and Joint Surg 42A 965 1960

Murdoch G Scoliosis in twins J Bone and Joint Surg 41B 736 1959

Nachlas I W & Borden J N The Cure of Experimental Scoliosis by Directed Growth Control J Bone and Joint Surg 33A 24 1951

Pease C N Injuries to the vertebrae and Intervertebral disc following Lumbar Puncture Am J Dis Child 49 849 1935

Perey O Contrast Medium Examination of the Intervertebral discs of the Lower Lumbar Spine Acta Orthopaed Scandinav 20 327 1951

Perey O Fracture of the Vertebral End plate in the Lumbar Spine Acta Orthopaed Scandina Suppl 25 1957

Roaf R The Treatment of Resistant Scoliosis Bull of the Hosp for Joint Diseases 19 120 1958

Roaf R Personal communication

Schwartzmann J R & Miles M Experimental Production of Scoliosis in Rats and Mice J Bone and Joint Surg 27 59 1945

Stearns G Jo-Yun Chen McKinley J & Ponseti I Metabolic Studies of children with Idiopathic Scoliosis J Bone and Joint Surg 37A 1028 19

Trueta M J Trauma and Bone Growth Septième Congrès International de Chirurgie Orthopédique p 379 1957

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END RESULTS IN THE TREATMENT OF MONTEGGIA FRACTURES

A Follow-Up Study of Twelve Cases

By

ÖSTEN HEDSTRÖM

Monteggia s fracture i e fracture of the ulna with dislocation of the radial head is fairly rare The mechanism of the injury is often difficult to reconstruct in detail and has to be ascribed to some unspecified fall as in bicycle accidents Frequently though a direct force upon the ulna can be discerned and the Monteggia fracture is sometimes regarded as a warding-off injury

The fracture is most common in children Thus in *Smith* s series for example 22 of the 25 cases were seen in individuals below 17 years of age The fracture appears to be equally common on both sides

From a therapeutic and prognostic point of view it is fundamentally important that two types of the fracture may be distinguished namely an extension type and a flexion type

The extension type is characterized by forward dislocation of the head of the radius and forward angulation of the ulnar fracture while the flexion type shows backward dislocation of the head and the fracture is angulated backwards The extension type is by far the most common and represents some 85–90 per cent of all Monteggia fractures The flexion type occurs almost exclusively in adults in whom it is almost as common as the extension fracture

As to treatment *Böhler Evans* and *Naylor* for example recommend closed reduction and claim that the vast majority of both extension and flexion fractures can be reduced by such manipulation *Smith Speed Watson Jones* and others however prefer open reduction particularly in the treatment of extension fractures *Watson Jones* however has reported good results of closed reduction of the flexion type of fracture

No unanimity has been achieved among the advocates of the open

reduction as to whether the radial head should be replaced at once or later. The annular ligament usually ruptures and *Smith Speed* and others claim that this ligament is most frequently interposed under the head of the radius thereby preventing reposition. This would make primary intervention the rational method. *Watson Jones* on the other hand stresses the risk of post traumatic myositis ossificans and therefore rarely interferes with the radial head at an early date, particularly since he has often observed the head to reassume its proper position *once the ulna fracture has been correctly reduced.* Internal fixation with the aid of plate and screws, Kirschner wire, Küntscher nail, Steinmann pin and recently also a Rush pin is now the rule in the operative management of the extension type of fracture.

The complications making the prognosis of Monteggia fractures doubtful are above all recurrent dislocation of the radial head and pseudarthrosis of the ulna.

According to *Watson Jones* (1940) the prognosis of these fractures is poor. He reported complete recovery without sequelae in only 2 of 34 cases. *Mobley & Janes* (1955) whose series consisted of 17 cases treated mainly by operation described the results as excellent in 2 and as good in 10. Evans who is an advocate of closed reduction reported full range of mobility in 5 out of 8 cases.

As mentioned above Monteggia fractures are fairly rare. Therefore our knowledge of these fractures can only be based on relatively small personal series. Accordingly it was considered justified to contribute a description of the fresh Monteggia fractures treated at the Departments of Orthopaedics in Lund and Malmo in the years 1946–1959.

The series consisted of 14 cases. One of these patients has however meanwhile died and one is still receiving treatment. The remaining 12 were reviewed.

TABLE 1

Age in years	Sex		Type of fracture		Treatment	
	M	F	Extension	Flexion	Closed	Opened
0–5	–	–	–	–	–	–
6–10	2	0	2	0	2	0
11–15	2	0	2	0	2	0
16–50	3	2	5	0	1	4
> 50	1	2	1	2	0	3
Total	8	4	10	2	5	7

The patients ages ranged from 6 to 74 years. Three of the fractures were due to direct violence – kick or blow by part of a machine. Two fractures were complicated. Only 33 per cent of the patients were below 16 years of age. As in most series on record extension fractures were five times as common as the flexion type. In 8 patients primary closed reduction was attempted but failed in 3, who were afterwards subjected to operation.

The operative methods varied somewhat. Intramedullary fixation was done in all 7 cases operated upon (3 with Rush pin, 3 with a Küntscher nail and one with Kirschner wire). The head of the radius was primarily exposed in 3 patients, all adults. In 2 of them the fractures were of the flexion type in which the head of the radius is usually more or less fragmented. The fragments or the entire head were extirpated. In the third patient, who had an extension fracture, the operator described interposition of the ruptured annular ligament. The ligament was replaced but not sutured.

All of the operations were performed within 6 days of the injury. In addition to the operation for the extraction of the nails or wire reoperation was necessary in 2 cases and then for excision of the head of the radius. In one of the cases, the one in which the annular ligament ruptured and was found to be interposed, re-dislocation ocurred after 2 weeks, and 7 months after the injury severe loss of the range of rotation made extirpation necessary. In the other case there developed considerable posttraumatic ossification around the radial head which had, however, not been exposed at the first operation.

The fractures were immobilized in plaster from 5 weeks (in a 6 year old child) to 3½ months (in a case of delayed healing of the ulna fracture) but was usually about 8 to 10 weeks.

In 7 cases the later course was uneventful, while the following complications ocurred in the remaining 5:

pseudarthrosis of ulna	2
delayed healing of ulna	1
myositis ossificans + redislocation of the radial head	1
myositis ossificans — transient radial paresis	1

The cases of pseudarthrosis which were not detected until the review claimed normal function and denied symptoms. The patients therefore refused operation. The diagnosis was, however, made roentgenologically and clinically no instability was demonstrable.

The results of treatment by the various methods are given in the table below where the patients are grouped according to type of therapy and to age In the table "excellent" is to be understood as freedom of all symptoms and signs "good" as full working capacity in the same occupation as before but with slight symptoms or slight loss of range of mobility of the elbow and "satisfactory" as some loss of working capacity and moderate loss of range of mobility The 2 patients with pseudarthrosis of the ulna were assigned to this group None of the results were so bad as to be classified as "poor" The shortest interval between the accident and the review was 11 months

TABLE 2

Treatment	Result		
	Excellent	Good	Satisfactory
open reduction	1	4	2
closed reduction	4	0	1
Age in years			
0– 5	–	–	–
6–10	2	0	0
11–15	1	0	1
16 50	2	3	0
> 50	0	1	2
	5	4	3

The analysis confirms the conclusions made by earlier workers in this field and shows that in children the prognosis is good and that the prospects are bright in cases in which the fracture has been successfully reduced by closed manipulation

In the present series the ulnar fracture often caused more concern than the dislocation of the radial head The probably scanty vascularization at the site of predilection of the fracture is thought to be responsible for the tendency to pseudarthrosis which can apparently only be counteracted by gentle operative technique and relatively long immobilization in plaster The use of intramedullary fixation particularly with a Rush pin instead of plates and screws is undoubtedly a step forward which is reflected in some measure in the improvement of the prognosis during the last decade

SUMMARY

The results of conventional treatment of 12 Monteggia fractures in 4 children and 8 adults are described In the children the fracture was treated successfully with closed reduction while in 7 of the adults open reduction proved necessary In all of these 7 some sort of intra medullary fixation was employed and it was found that the Rush pin could be used with advantage Of the operated patients 5 have returned to their usual occupation without loss of working capacity and in the remaining 2 working capacity and range of mobility of the elbow are somewhat reduced The slow healing of the ulna fracture was the greatest problem in the present series

RÉSUMÉ

Les résultats du traitement conventionnel de 12 fractures Monteggia chez 4 enfants et 8 adultes sont décrits Chez les enfants les fractures ont été traitées avec succès par réduction fermée tandis que chez 7 des adultes il s est montré nécessaire d effectuer une réduction ouverte

Chez tous les sept on a utilisé une sorte d enclouage intramedullaire et on a découvert que la broche Rush pouvait être utilisée avantageusement Parmi les malades opérés 5 avaient repris leurs occupations habituelles sans perte de capacité de travail et chez les 2 autres la capacité de travail et l étendue de la mobilité du coude étaient quelque peu réduites C est la lente guérison de la fracture du cubitus qui a posé les plus grands problèmes dans la présente série de cas

ZUSAMMENFASSUNG

Die Ergebnisse der konventionellen Behandlung von 12 Monteggia Brüchen bei 4 Kindern und 8 Erwachsenen werden beschrieben Die Brüche der Kinder wurden erfolgreich mittels unblutiger Einrichtung behandelt wärend bei 7 der Erwachsenen die offene Einrichtung vorgenommen werden musste Bei allen sieben wurde eine Form der intramedullären Nagelung angewendet und man fandt dass der Rush Nagel mit Vorteil anbewendet werden konnte Von den operierten Patienten konnten fünf ihre gewöhnliche Beschäftigung ohne Herabsetzung der Arbeitsfähigkeit wiederaufnehmen während bei den beiden übrigen dit Gebrauchsfähigkeit und der Bewegungsumfang des Ellbogens etwas herabgesetzt sind Die langsame Heilung des Bruches der Ulna war das grösste Problem in diesen Fällen

REFERENCES

Blount W P Fractures in Children Baltimore 1954
Bohler L Technik der Knochenbruchbehandlung Vienna 1951
Bush L F & McClain F J Am Acad Orthop Surg Instructional Course Lect *16* 256 1959
Cunningham S R J Bone & Joint Surg., *16* 351 1934
Curry G J Am J Surg 73 613 1947
Evans E M J Bone & Joint Surg *31 B* 578 1949
Cylling B Opuscula Medica 3 2?9 1958
Mobley J E & Janes J M Proc Mayo Clin *30*(2? 497 1955
Naylor A Brit J Surg 29 323 194?
Penrose J H J Bone & Joint Surg *33 B* 65 1951
Sayle Creer W Proc Roy Soc Med *40* 241 1947
Smith F M Surgery of the Elbow Springfield 1954
Smith F M Surg Gynaec and Obstet *85* 630 1947
Speed J S & Boyd H B J A M A *115* 1699 1940
Thompson H A & Hamilton A T Am J Surg., *79* 579 1950
Trojan E Arch Orthop Unfall Chir *48* 377 1956
Watson-Jones R Fractures and Joint Injuries Edinburgh 1955
Wustmann O Die Chirurgie des Ellbogengelenkes Berlin 1954
Zachariae L Nord Med *47* 730 195?

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PELVIC INSTABILITY IN UPPER FEMORAL EPIPHYSEOLYSIS

By

GEORG THEANDER

The condition known as slipped upper femoral epiphysis or epiphyseolysis is characterized by a more or less gradual separation of the femoral diaphysis from the capital epiphysis, which remains in the acetabulum. A bending or fracture through the upper femoral epiphyseal plate and contiguous trabeculae of bone seems to be an essential regular finding observed on microscopic examination of specimens taken shortly after the commencement of slipping (*Sutro* 1935, *Howorth* 1941, 1949, *Ponseti* & *McClintock* 1956). In practice the diagnosis is based on the recognition of the displacement, but it is widely agreed that the fracture as well as the actual slipping or epiphyseolisthesis is merely the final result of some abnormality of the epiphyseal plate. The common absence of any known trauma strongly supports this conception. There is much evidence that some hormonal disorder (*Key* 1926 and others), poisonous agent (*Ponseti* & *McClintock* 1956 and others) or a combination of both (*Andrén* & *Borgström* 1958 and others) is involved in the causation of the disease.

Little is known with certainty of the metaphyseal changes preceding the epiphyseolisthesis. It has been claimed by many authors (e.g. *Ferguson* & *Howorth* 1931, *Brailsford* 1933, 1953), though denied or doubted by others (e.g. *Waldenström* 1940, *Watson Jones* 1955), that a preslipping stage of the disease can be clinically distinguished, but the histologic picture referred to this stage seems to be fairly uncharacteristic. *Howorth* (1941, 1949) observed decalcification and hypervascularity at the junction of the neck and the epiphyseal disc together with villous formation, oedema, hypervascularity and some perivascular cell infiltration of the joint soft tissues. Roentgenographic changes said to precede slipping have been reported by *Ferguson* &

Howorth (1931) and *Brailsford* (1933 1953) According to *Brailsford* (1933) the metaphysis may be thickened in part or throughout the whole of its width In such cases the metaphyseal periphery of the epiphysis will be well defined the diaphyseal border on the other hand will be ill defined and woolly in appearance

A gradual slipping of other epiphyses is known to occur (e g *Greene* 1954) but seems to be rare This does not necessarily mean that the metaphyseal abnormality supposed to underlie epiphyseolisthesis is usually restricted to the upper femoral ends With a corresponding degree of reduction in its shearing strength any other epiphysis would probably be less apt to slip than that of the upper femoral end because of the oblique position of the epiphyseal plate there Though it would certainly be of interest to ascertain whether upper femoral epiphyseolisthesis is the manifestation of a merely local or a general metaphyseal abnormality this problem has apparently received little attention A fairly thorough search in the literature thus revealed only one statement with no further details that skeletal surveys of patients with slipped upper femoral epiphysis have shown some widening and irregularities in the outlines of other epiphyseal plates which suggests that the lesions are not restricted to the upper portion of the femur (*Ponseti & McClintock* 1956 *Ponseti* 1957) The present paper is concerned with the question whether the primary lesion also involves connective tissues other than those of the metaphyses of bones

MATERIAL, METHODS AND RESULTS

The material included 28 cases of upper femoral epiphyseolysis in the slipping or postslipping stage The essential data are summarized in Table 1 The sex ratio was somewhat unusual since only 12 of the 28 were boys but in no other respect did the series seem to differ from others on record In 5 cases (Nos 1 to 5) roentgenographic examinations were performed for the purpose of ascertaining whether the bony pelvis was stable or not In the others the study was retrospective and had to be based on the review of films taken only to establish the diagnosis of slipped upper femoral epiphysis or to reveal any changes in this condition following treatment For comparison 11 apparently healthy youths (3 boys and 8 girls aged 10 to 18 years) were also examined for pelvic instability

The study was prompted by observations made on roentgenographic examination of a 12 year old girl (Case No 1) for upper right femoral

TABLE 1

Slipped upper femoral epiphysis: sex and age distribution, side of hip affected and observed symphyseal gliding (C)

Case No	Sex	Age in years	Hip affected	C
1	F	12	R	+
2	F	14	R	+
3	F	14	L	—
4	M	16	L	—
5	M	14	R	—
6	F	11	L	+
7	F	12	L	+
8	F	12	L	+
9	F	10	L	+
10	F	13	L	+
11	F	13	R L	—
12	F	13	R	—
13	F	13	R	—
14	F	12	R	—
15	F	11	L	—
16	F	12	R L	—
17	F	12	L	—
18	F	13	L	—
19	M	14	R L	+
20	M	13	L	+
21	M	14	L	+
22	M	17	L	—
23	M	15	L	—
24	M	14	L	—
25	M	13	L	—
26	M	10	L	—
27	M	13	R	—
28	M	11	R L	—

epiphyseolysis suggested by symptoms of 2 months' duration. This diagnosis was confirmed and, in addition, the pubic symphysis was found to be remarkably skew, the end of the left pubic bone being in the recumbent position situated more cranially than that of the right one. Further examination in the erect position revealed a definite instability of the pelvis, the symphyseal ends of the pubic bones gliding on one another on transfer of the body weight from one leg to the other. On re-examination 15 months later, the symphyseal skewness persisted but pelvic instability was no longer demonstrable. Of 4 further patients

with unilateral upper femoral epiphyseolysis (2 boys and 2 girls Cases Nos 2 to 5) who were examined in the same manner mutual gliding of the pubic bones was demonstrated in one In the others no such movement was observed but in 2 of them the symphysis was skew

The 23 cases of upper femoral epiphyseolysis which were studied in retrospect only (Nos 6 to 28) had been repeatedly examined roentgenographically but as mentioned not for any pelvic instability and only *in the recumbent position On comparison of the films available* it was nevertheless apparent that a mutual gliding of the pubic bones had occurred in 8 of the cases In the remaining 15 cases the pubic bones were not seen to have moved in relation to one another after the first film had been taken but in 7 of them the symphysis was skew

Symphyseal gliding was thus observed to occur in 10 out of the 28 cases of epiphyseolysis studied and in 9 of those with no observed gliding the symphysis was skew (Tables 1 and 2) Extensive investigations on pelvic instability and its sequelae seem to indicate that such skewness is per se a reliable sign that the pelvis is or has been unstable (*Kamieth & Reinhardt* 1955 *Kamieth* 1959)

TABLE 2

Symphyseal skewness related to side of slipping in upper femoral epiphyseolysis with no observed symphyseal gliding r=right l=left pubic bone situated more cranially

Case No	Hip affected	Symphyseal skewness
3	L	r
4	L	l
5	R	–
11	R L	l
12	R	r
13	R	–
14	R	l
15	L	r
16	R L	–
17	L	l
18	L	–
22	L	r
23	L	–
24	L	–
25	L	r
26	L	–
27	R	–
28	R L	–

TABLE I

Slipped upper femoral epiphysis sex and age distribution side of hip affected and observed symphysial gliding (G)

Case No	Sex	Age in years	Hip affected	G
1	F	12	R	+
2	F	14	R	+
3	F	14	L	—
4	M	16	L	—
5	M	14	R	—
6	F	11	L	+
7	F	12	L	+
8	F	12	L	+
9	F	10	L	+
10	F	13	L	+
11	F	13	R L	—
12	F	13	R	—
13	F	13	R	—
14	F	12	R	—
15	F	11	L	—
16	F	12	R L	—
17	F	12	L	—
18	F	13	L	—
19	M	14	R L	+
20	M	13	L	+
21	M	14	L	+
22	M	17	L	—
23	M	15	L	—
24	M	14	L	—
25	M	13	L	—
26	M	10	L	—
27	M	13	R	—
28	M	11	R L	—

epiphyseolysis suggested by symptoms of 2 months duration This diagnosis was confirmed and in addition the pubic symphysis was found to be remarkably skew the end of the left pubic bone being in the recumbent position situated more cranially than that of the right one Further examination in the erect position revealed a definite instability of the pelvis the symphyseal ends of the pubic bones gliding on one another on transfer of the body weight from one leg to the other On re examination 15 months later the symphyseal skewness persisted but pelvic instability was no longer demonstrable Of 4 further patients

by the characteristic sex and age distribution of the disease (roughly 10 to 16 years boys more often than girls) and by its relatively common occurrence in individuals growing rapidly or affected with the adiposo genital syndrome (*Key* 1926) *Experimental studies of the influence* of growth hormone oestrogen and testosterone on the shearing strength of the upper tibial epiphysis in rats seem to indicate that epiphyseo listhesis can result from an imbalance between the growth and sex hormones (*Harris* 1950 *Hillman & coll* 1957) Further support is given to this view by the slipping of the upper femoral epiphysis re ported to occur in some cases of craniopharyngeoma (*Mason* 1954 *Bruns* 1960) tumour of the hypophysis (*Lofgren* 1953) or hypophyseal dwarfism (*Schlüter & Peter* 1956) and by the small size of the sella turcica observed in several cases of slipped upper femoral epiphysis (*Lofgren* 1953) On the other hand epiphyseolysis is far from always associated with any demonstrable hormonal disorder and in an exten sive study of a hundred cases of the disease *Burrows* (1957) failed to reveal any fundamental difference in the natural history of those with manifest endocrine defects and those without

A further possible etiologic factor was suggested by the observation that epiphyseolisthesis as well as many other pathologic conditions can be induced in animals by oral administration of aminonitriles (*Ponseti & Shepard* 1954 and others) Histologically the lesions thus obtained in the epiphyseal plates are similar to those observed in the slipped upper femoral epiphysis in humans (*Ponseti & McClintock* 1956 *Ponseti* 1957) Since the onset of symptoms in the latter condition shows a distinct seasonal variation (*Ferguson & Howorth* 1931 *Andren & Borgstrom* 1958) the period of increased frequency coinciding with the months the cows are out to pasture and since many patients with slipped upper femoral epiphysis are known to be heavy milk drinkers (*Kocher* 1894 *Andren & Borgstrom* 1958) it has been assumed that traces of amino nitriles may be supplied with the milk and favour epiphyseolysis in ra pidly growing individuals (*Andren & Borgstrom* 1958) This assumption is supported by an observation made by *Selye & coll* (1957) that the *toxicity of aminoacetonitrile is markedly enhanced by simultaneous* injection of growth hormone even in doses too small demonstrably to stimulate growth

It would seem to be in line with and even in support of the concep tions related above if the pathologic process supposed to underlie epi physeolisthesis were *found to involve other structures as well as the* metaphyses of bones since the hormones and poisons referred to are

pluripotent in action The inherence of pelvic instability in the disease as suggested in the present investigation is nevertheless puzzling It is well known that such instability can be experimentally provoked and is physiologically produced during pregnancy by the combined or alternate action of relaxin and oestrogen (*Hall* 1956 and others) even in old men pelvic instability may follow treatment with stilbene (*Bucher & Kamieth* 1956) The pelvic laxity including marked instability of the symphysis recently discovered in congenital dislocation of the hip (*Andren* 1960) is also due to some disorder of oestrogen metabolism (*Andren & Borglin* 1960) But in the metaphyses of bones as represented by the upper tibial ends in rats oestrogens cause an increase in the shearing strength (*Harris* 1950 *Hillman & coll* 1957) A decrease can on the other hand be provoked by the growth hormone (*Harris* 1950) but as far as is known pelvic instability can not be induced by overexposure to growth hormone The controversy of evidence thus apparently present might suggest a more complicated interaction of causal factors in epiphyseolysis than hitherto supposed

SUMMARY

Pelvic instability was found to occur in at least 10 out of 28 cases of upper femoral epiphyseolysis studied The condition was considered to be inherent in the abnormality underlying epiphyseolisthesis and the theoretical aspects of the observation are discussed on the basis of current conceptions of the etiology of the disease

RESUME

On a constate une instabilite pelvique dans au moins 10 cas d une *serie de 28 observations d epiphyseolyse fémorale superieure* Cet etat a ete considere comme une anomalie inherente a celle de l epiphyseolisthese Les aspects theoriques de cette observation sont discutes sur la base des conceptions ordinaires de l etiologie de cette maladie

ZUSAMMENFASSUNG

Beckeninstabilitat war zumindest in 10 von 28 Fällen die wegen Epiphyseolyse der oberen Femurepiphyse untersucht worden waren vorhanden Der Zustand wurde als an die zugrundeliegende Anomalie der Epiphyseolisthesis gebunden angesehen und die theoretische Seite

der Beobachtung wird auf grund der gelaufigen Auffassung der Ursache der Erkrankung besprochen

REFERENCES

Andrén L Acta radiol 54 123 1960
Andren L & Borglin N E Acta orth scand 30 169 1960
Andrén L & Borgstrom K-E Acta orth scand 28 29 1958
Brailsford J F Lancet 16 1933
Brailsford J F The radiology of bones and joints 5th ed., p 272-284 1953 J & A Churchill Ltd London
Bruns D Zschr f Orth 92 453 1960
Burrows H J J Bone Joint Surg 39 B 641 1957
Bucher H K & Kamieth H Zschr f Urol 49 337 1956
Caffey J Pediatric X ray diagnosis 2nd ed p 683 1950 Year Book Publ., Chicago
Ferguson A B & Howorth M B J A M A 97 2 1867 1931
Greene R Proc R Soc Med (London) 47 446 1954
Hall K J Physiol (London) 134 3 P 1956
Harris R J Bone Joint Surg 32 B 5 1950
Hillman J W Hunter W A & Barrow J A Surg Forum 8 566 1957
Howorth M B Surg Gyn Obst 73 723 1941
Howorth M B J Bone Joint Surg 31 A 734 1949
Kaiser G Deutsche Gesundheitswesen 8 1474 1953
Kamieth H Zschr f Orth 91 297 1959
Kamieth H & Reinhardt K Fortschr Rontgenstr 83 530 1955
Key J J Bone Joint Surg., 8 53 1926
Kocher T Deutsche Zschr f Chir 38 521 1894
Lofgren L Acta chir scand 106 153 1953
Mason A S Discussion following Greene R 1954
Ponseti I V Clin Orth 9 131 1957
Ponseti I V & McClintock R J Bone Joint Surg 38 A 71 1956
Ponseti I V & Shepard R S J Bone Joint Surg., 36 A 1031 1954
Rennie A M J Bone Joint Surg 42 B 273 1960
Schlüter K & Peter E Arch f Orth u Unfallchir 48 270 1956
Selye H Arch f exp Path u Pharmak 230 155 1957
Selye H & Bois P Proc Soc Exp Biol Med 94 133 1957
Selye H & Ventura J Amer J Path., 33 919 1957
Sutro C J Arch Surg., 31 345 1935
Wallenström H Surg Gyn Obst 71 198 1940
Watson-Jones R Fractures and joint injuries 4th ed p 6 4-664 19 E & S Livingstone Ltd Edinburgh London

MUSCLE FUNCTION OF TRANSPLANTED FLEXOR MUSCLES IN THE THIGH IN PERIPHERAL PARALYSIS OF EXTENSOR MUSCLES

By

KÅRE HAUG

The development of this method of operation dates back to *Nicoladoni* (1) who in 1880 suggested transplantation of tendons in the treatment of paretic muscles. The first transplantation of the biceps flexor femoris to the patella was performed by *Goldthwait* (2) in 1896. This operation was done for the relief of quadriceps femoris paralysis in residual poliomyelitis. In addition *von Eulenburg & Sonnenburg* (3) described the method in the treatment of Morbus Little in which the stronger flexors of the femoris caused contracture of the knee joint.

The main purpose of the operation is to make the use of the knee bandage unnecessary and to improve gait (4). But as late as 20–30 years ago the range of indications for operation was still narrow: if the patient could overcome his quadriceps gait, the operation was considered contra-indicated (5). In slight quadriceps paresis knee bandages and the like were recommended (6). It was long believed that paralysis of the gastrocnemius, *i.e.* the muscle normally preventing recurvation of the knee, made a really successful operation impossible. Neither was transposition performed if gluteus maximus function was impaired, it being feared that it would result in a stooping carriage of the body. In recent years, however, excellent results of transpositions have been achieved even in patients with paralysis of the gluteus maximus and gastrocnemius (4).

The static equilibrium in the erect position is the key to the understanding of important problems concerning quadriceps paralysis with consequent knee joint contractures.

Normally the centre of gravity of the body passes through the knee or just in front of the knee if the subject is standing with the quadriceps relaxed (Fig. 1 a). In quadriceps paralysis the posture of the

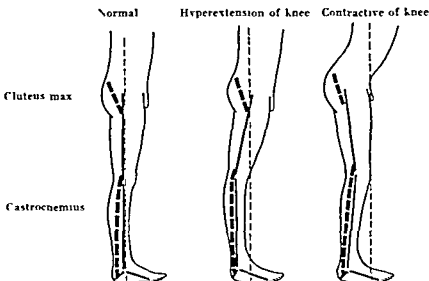


Fig 1
STATISTICAL EQUILIBRIUM
(interrupted line denotes axis of gravity of body)

patient is such that the axis of gravity passes through a point some distance before the knee which is hyperextended (Fig 1 b) Then the power of gravity is balanced against the gluteus maximus and gastrocnemius In the presence of contracture of the knee joint the centre of gravity of the body shifts still further forward (Fig 1 c) This is accompanied by increased lumbar lordosis and the condition can simulate contracture of the hip joint

In quadriceps paralysis the gait is unsteady because if the knee is loaded when flexed it is liable to give way owing to inadequate reflex contraction of the quadriceps The gait is slow because of the lack of acceleration of the extension of the knee (7)

The question of flexion of the knee is dependent mainly on the ratio between the strength of the transplanted thigh flexors and the hamstrings that are still intact Modern handbooks on orthopaedics also warn against transplantation of all hamstrings (8)

The principle of the method of transplantation is the same as that originally suggested to counteract instability and to improve joint function by reconstruction of the stretch muscles A number of variations concerning the type and number of incisions of the skin and the choice of muscles have been recommended (9)

In the beginning only the biceps was transplanted In *Schwartzmann & Crego* s series of 1948 this method produced lateral dislocation of the patella and consequent limitation of extension of the knee in 40 %. The dislocation was reduced by shifting the attachment on the tibular tuberosity medially or by transplanting the semitendineus to the patella

The former belief that the 5 flexors originating from the tuber ischii must also be loosened and transplanted anteriorly so that the origin process will not be situated behind the axis of flexion of the knee joint and that the tensor fascia lata is less suited for transposition because it is capable of a certain extension in the knee has long been abandoned (10) For it has even been shown that transposition of the tensor alone with dissection of the iliotibial tract which has been passed like a cord through a tunnel on the anterior aspect of the quadriceps and fastened to the tibial tuberosity gives good extension of the knee and a much better gait (11)

It has long been realized that it is necessary to loosen the tendon and the muscle as high up in the thigh as possible without however injuring the nerves or vessels supplying the muscle This gives the straightest possible course of the transplanted muscle It is also important to fasten the tendon directly to bone in the patella and if the tendon is long enough also to the tibial tuberosity

It is not necessary to correct any contracture of the knee before transplantation of the muscle tendon in contrast to what was formerly believed (6) It is the increased tonus of the flexors of the knees that tends to cause contractures It is therefore sufficient to straighten out the knee during operation when the flexors have been loosened from their attachments

At the Kysthospitalet ved Stavern the following operation method has been used (12)

1 Bylow Hansen s incision of the skin which consists of a medial and lateral longitudinal incision of the thigh Both incisions are begun in the upper part of the thigh and extend downwards dorsally then swing anteriorly the medial incision towards the pes anserinus the lateral over the fibular head towards the tibial tuberosity This provides a good approach to the thigh muscles and their attachments In addition the lateral incision enables exposure of the patella the patellar ligaments and the tibial tuberosity

2 Each muscle is dissected separately high up in the thigh and passed through preformed subcutaneous channels subcutaneously with as straight a course as possible towards the patella

3 The tendons are fastened intra osseally with strong sutures to the patella and tibial tuberosity (As a rule the biceps reaches only to the lower border of the patella)

4 Sometimes the iliotibial tract is rotated 180 about its axis and attached to the patella so that it will cover the transplanted hamstrings

5 Any contracture of the knee is corrected during the operation and the knee is fixed in the corrected position in plaster bandage for 8 weeks after operation

Active muscle traction of the patella is started early after the operation Active exercise of the transplanted muscles is an important part of treatment

AUTHORS SERIES

The present series consisted of patients operated at the Kysthospitalet ved Stavern during the last 10 years with transposition of the flexors of the thigh because of quadriceps femoris paralysis or paresis in residual poliomyelitis

A total of 23 operations were performed on 20 patients 3 of the patients having been operated upon bilaterally 7 were excluded 5 because they had been followed up for less than 6 months and 2 because they had moved so far away This left 15 operations on 13 patients

The after investigation consisted of simple clinical examinations All the patients were re examined by the author

Voluntary contraction of the transported muscles could be palpated in all of the cases except one In that case the biceps had shown marked fatty degeneration already during the operation

A measure of the power of contraction of the transported muscles can be obtained by reading the number of degrees the patient is able to extend the loosely hanging leg

Table 1 shows the pre operative range of extension of the knee which muscles are transplanted and their state (healthy or degenerated) and the extension of the knee measured at the after-examination It is *noteworthy that in one case in which the biceps was paralyzed* the semitendinosus alone could not produce extension In another case in which only the biceps was transplanted the operation had only had weak effect on extension Without including the biceps 2 or 3 of the medial flexors can give satisfactory extension

An important question is whether any change occurs with time in the range of contraction of the transplanted muscles In the 9 cases in

TABLE 1

Preoperative test		Transposed muscles, paralyzed muscles						Postoperative test
Op nr	Quadriceps	[illegible]	Gracilis	Semitendinosus	Semimembranosus	Sartorius	[illegible]	Extension of knee 0-90 degree
1	0		(+)	(+)			+	45
2	0			+	+	+		0
3	0	−	+	(+)		+		90
4	(+)	(+)		+			−	0
5	(+)	+	−	(+)		+	(+)	90(50)
6	0	−	+				+	65
7	0	+	(+)			(+)	+	60
8	0	−					+	30
9	0	(+)		−				45
10	+		+			+		65
11	(−)	−	(−)			+		45
12	0	−				−	+	90
13	0	−	(+)	+			+	65
14	−	(+)	(−)	(−)		−		60
15	0	+	+	(+)		+		80

TABLE 2

Postoperative function of knee as judged by range of extension

Op nr	1 measurement	2 measurement	Difference
1	50 degrees	45 degrees	— 5 degrees
2	90 „	70 „	—20 „
3	80 „	90 „	+10 „
4	55 „	50 „	— 5 „
5	55 „	65 „	−10 „
6	45 „	60 „	−15 „
	40 „	50 „	—10 „
8	60 „	65 „	+ 5 „
9	75 „	65 „	—10 „

which the extension of the knee was measured on at least 2 occasions, it was increased in 4 and decreased in 5 (Table 2, Fig. 2).

It is uncertain whether the changed functional conditions of the transplanted muscles have any effect on their functional capacity. It was tested by watching the patient when climbing stairs because then

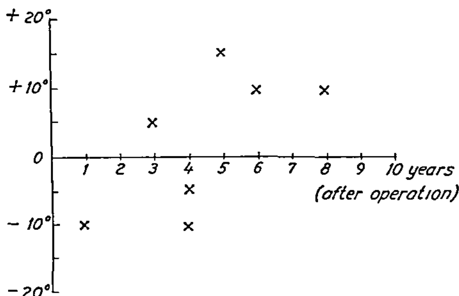


Fig 2

Positive and negative changes in extension of knee joint and time of measurement

TABLE 3

Postoperative improvements

Operation	I[illegible] stability of knee	Manage without bandage	Manage without sticks (crutches)	Gait improved	Less marked lumbar lordosis	Less marked contracture of knee joint
1	×			×	×	10–0 degrees
2	×			×	×	30–0 „
3	×		×	×	×	40–0 „
4						10–0 „
5	×			×	×	
6	×	×	×	×		10–0 „
7	×	×	×	×		5–0 „
8	×	×		×		15–0 „
9	×	×		×		
10	×			×	×	15–5 „
11	×	×		×		
12	×	×	×	×		25–0 „
13	×			×		25–8
14	×	×		×	×	20–10 „
15	×			×		25–0 „

the slightly flexed knee must be extended several times in succession while weight bearing In 8 occasions the results of the test were satisfactory and in all of them the patients reported that it was easier to walk upstairs after the operation and that this improvement had been permanent

Table III gives a survey of the post operative improvements All except one reported a feeling of improved stability of the knee i e after 14 of 15 operations In 8 cases the patients were able to manage without a supporting bandage or crutches The series included 12 contractures of the knee which disappeared completely or partially after the operation

A decrease of the valgus of the knee from 20 to 5 degrees on one leg and from 10 to 5 on the other was noted in a boy who had been operated upon at 10 and 11 years of age In a girl operated upon at 12 years the valgus decreased from 15 to 10 degrees

The side effects of transposition are relatively slight Flexion of the knee becomes slightly weaker but this is of little functional importance It is known that good function of the gastrocnemius is necessary for active flexion of the knee after operation Satisfactory function was found after 10 of 11 operations In the case of lacking knee flexion the gastrocnemius before operation was weak (+3) and the re examination took place only half a year after the operation It was noteworthy that a boy with impaired function of the gastrocnemius bilaterally was nevertheless able to manage without crutches and supporting bandages and is now able to walk with slight recurvation of the knees for more than 1 kilometer at a time Recurvation of about 5 degrees during weight bearing of the leg was noted in 4 cases In one case in a girl it was 30 degrees She was operated upon at 12 years and then had a flexion contracture of 25 degrees The medial hamstrings were very weak and were not able to withstand the pull of the strong transported muscles But the patient is not troubled by this residual contracture and has a normal gait In another case in which all the hamstrings were transplanted and the gastrocnemius was weak a 30 degree contracture disappeared but strangely enough no recurvation developed The above mentioned lateral dislocation of the patella was not seen in the present material It occurred in a patient who had been operated upon elsewhere and disappeared after transposition of the medial hamstrings

Stiffness of the knee was reported by 6 patients but in 5 it was only slight One patient reported slight weakness of the knee This weakness

appeared after he had walked about 100 meters. Only one complained of transient pain in the knee after the operation.

One patient had no benefit from the operation apart from elimination of a 10 degree flexor contracture. That patient had severely fatty degeneration of the biceps and a healthy semitendinosus as the only available muscle for transposition.

In one case a satisfactory reconstruction of the extensors was spoilt by a supracondylar fracture of the femur. In another the extensor function was severely impaired on forced passive flexion of the knee during parturition. After later reconstruction of the ruptured patella ligament, extension was again good.

TABLE 4

Results of transposition of muscles for quadriceps paralysis in residual poliomyelitis

	Excellent	Good	Fair	Satisfactory	Bad	C
(4) Schwartzmann and Crego (1948)	67 %	7 %	13 %	87 %	13 %	134
(13) Noe, Ziegler, Herrera (1949)				93 %	7 %	27
(14) Canadell, Carafi, Barraquer Bordas (1955)				96 %	4 %	56
Kysthospitalet ved Stavern (1960)		67 %	24 %	94 %	6 %	15

Excellent: 1) normal strength of active extension 2) no recurvation 3) manage without bandage 4) no lateral displacement of patella 5) knee stable when walking.

Good: 1) active extension 45–90 degrees (135–180) 2) slight or no recurvation 3) 4) 5) as for excellent.

Fair: 1) active extension 5–45 degrees (95–135) 2) slight or moderate recurvation 3) 4) 5) as for excellent.

Bad: 1) no extension 2) severe, painful and disturbing recurvation 3) need bandage 4) lateral displacement of patella 5) unstable when walking.

RESULTS OF AFTER-EXAMINATION

To facilitate comparison the results are given in percentages despite the fact that the material was so small and heterogeneous.

The cases are graded in accordance with the recommendations of *Schwartzmann & Crego* (1948).

Good agreement was found between the objective findings and the

answers given by the patients concerning the improvement after the operation Only one patient reported that the condition was the same as before the operation

DISCUSSION

It is clear from Table 1 that the range of indications for transplantation of the thigh flexors in paralysis of the quadriceps in residual poliomyelitis was wide since even muscles with fatty degeneration and weak muscles were often used The results of the operation must therefore be evaluated in the light of the wide range of indications

That the results were so good must be ascribed above all to the operation method used It is important that the large incision of the skin enables evaluation of the quality of the muscles and their course after transposition Correction of knee contractures before operation can in our opinion weaken the thigh flexors because they are then overstretched It is therefore advantageous to correct contractures during the operation after the first thigh flexor to be transplanted has been loosened from its attachments

It is perhaps possible with Yount s technique to improve extension of the knee still more if the tensor fascia lata is good According to that method the part of the gluteus maximus that is inserted into the iliotibial tract as well as tensor is used We have no experience with this method

As mentioned previously contracture of the knee joint can result in increased lumbar lordosis (Fig 1 c) Conversely it may be assumed that an elimination of the contracture of the knee will result in a correction of lumbar lordosis This point did not receive sufficient attention before operation Nevertheless an improvement of the lumbar lordosis was often seen in those cases in which contracture had been eliminated (Table 3)

Valgus of the knee decreased after 3 operations In one case where only the biceps had been transplanted and not the iliotibial tract the valgus decreased less than expected (from 15 to 10 degrees) It is therefore possible that a tense tractus iliotibialis is equally important as a contracted biceps as a cause of valgus Otherwise the biceps is regarded as an important factor in the cause of valgus knee flexion and rotation of the tibia in quadriceps paralysis (15)

Although recurvation sometimes occurs as a consequence of muscle transplantation this risk is as shown not so great and therefore one

should not attach too much importance to it in the evaluation of indications for operation Neither does recurvation seem to disturb the patient at all

CONCLUSIONS

The present after examination of patients operated upon with transplantation of the flexor muscles of the thigh because of quadriceps paralysis and paresis in residual poliomyelitis have shown that

in this series as well as in those earlier published this operation prove to be of great value

it is unnecessary to correct any knee joint contracture before operation

it is probable that knee joint contracture will result in increased lumbar lordosis

increased valgus of the knee can decrease after transposition of the biceps and iliotibial tract and

forced passive flexion of the knee can severely impair function of the transplanted muscles

RESUME

Il est donne un aperçu des vues anterieures sur les indications de la transposition des tenseurs de la cuisse dans les cas de paralysie du quadriceps due a la poliomyelite La base theorique du principe de la methode de transposition a ete cherchee dans l equilibre statique du corps Des détails importants de l operation sont releves et la methode de l operation appliquee par l hopital Kysthospitalet de Stavern est decrite

Les observations recueillies durant une periode de 10 ans se rapportent a 20 malades chez lesquels il a ete pratique 23 operations 13 malades representant 15 operations ont ete reexamines par l auteur qui leur a fait subir un simple examen clinique

Dans 4 cas on a constate que le pouvoir de contraction etait accru et dans 5 cas diminue durant la periode de l observation Les conditions modifiés des fonctions des muscles transposes ne paraissent pas influer sur leur capacite de travail que l on a cherche a apprecier par des essais sur des escaliers

Les ameliorations post operatoires et les conséquences deleteres qui peuvent suivre l operation sont examinées en detail Il est mentionne en

particulier une réduction observée de la valgidité du genou et une diminution de la lordose lombaire après l'opération

Les résultats obtenus s'établissent au niveau de ceux publiés antérieurement puisque 94 % étaient satisfaisants Dans un cas l'opération n'a eu aucune utilité sauf qu'une contracture de 10 degrés de l'articulation du genou a été éliminée

Il est mentionné 2 cas où le bon résultat de la transposition des muscles a été anéanti l'un par une fracture supra condylaire du fémur l'autre par une flexion passive forcée au cours d'un accouchement Dans une reconstruction ultérieure du ligament patellaire rompu l'extension a de nouveau été améliorée

ZUSAMMENFASSUNG

Eine Übersicht von früheren Auffassungen der Indikationsstellung für die Transposition von Oberschenkelbeugern bei der poliomyelitischen Lähmung des Quadriceps wird gegeben Die theoretische Grundlage für das Prinzip der Transposition wird im statischen Gleichgewicht des Körpers gesucht Wichtige Einzelheiten der Operation werden hervorgehoben und die Operationsmethode welche man am Kysthospital Stavern verwendet wird beschrieben

Das Material welches von einer Zehnjahrsperiode gesammelt wurde besteht aus 20 Patienten und es wurden 23 Operationen ausgeführt 13 Patienten mit insgesamt 15 Operationen wurden vom Verfasser mit einfachen klinischen Mitteln untersucht

In 4 Fällen hat man eine Zunahme und in 9 Fällen eine Abnahme der Kontraktionskraft während der Beobachtungszeit gefunden

Die veränderten Funktionsbedingungen für die transponierten Muskeln scheinen nicht auf ihre Arbeitsfähigkeit einzuwirken was mittels der Treppenprobe zu beurteilen versucht wurde

Die postoperativen Verbesserungen und deletären Folgen werden bis ins Einzelne durchgegangen Besonders wird die postoperative Abnahme der Valgität im Knie und der Lumballordose besprochen

Die erreichten Resultate stehen auf gleicher Höhe mit vorhergehenden Veröffentlichungen da 94 % zufriedenstellend waren In einem Fall war die Operation nutzlos abgesehen das[illegible] eine Kniegelenkskontraktur von 10 beseitigt wurde

Man erwähnt zwei Fälle in denen das [illegible] l
transponierung ruiniert wurde in einem F[illegible] lare
Fraktur in dem anderen durch ü[illegible]s

einer Geburt Mittels einer späteren Wiederherstellung des lig patellae wurde die Extension neuerlich gebessert

REFERENCES

1 *Nicoladoni C* Ueber Sehnentransplantation Aus d chir Sekt d 54 Versammlung Deutsch Naturforscher u Artze in Salzburg 1880
2 *Goldthwait J E* Tendon Transplantation in the Treatment of Deformities Resulting from Infantile Paralysis Boston Med and Surg J CXXXIII 447 1895
3 *Hoffa Albert* Lehrbuch der Orth Chir Stuttgart 1905 s 144
4 *Schwartmann & Crego* Hamstring tendon transplantation for the relief of quadriceps femoris paralysis J Bone Surg., 30A 514 1948
5 *Crego & Fischer* Transplantation of biceps for the relief of quadriceps femoris paralysis in residual poliomyelitis J Bone and Joint Surg XIII,3 515 1931
6 *Debrunner H* Die Behandlung der Quadriceps Lachmung Z Orthop 70 164 1940
7 *Steindler A* Kinesiology of the Human Body Publisher Charles Thomas p 3 6 357
8 *Lange M* Orthopaedisch chirurgische Operationslehre Munchen 1951
9 *Bier Braun Kümmel* Chirurgische Operationslehre bind IV 459–462 1933
10 *Silverskiold* Ueber Quadricepsplastik Verhandlungen der Deutschen Orthopaedischen Gesellschaft 16 Kongress 1921
11 *Josserand* Transplantations du tenseur du fascia lata pour une paralysie du quadriceps Lyon chir 31 704 1934
12 *Stören H* Some Experiences of Transposition of the Hamstrings in Paralysis after anterior Poliomyelitis Act Orthop Scand XXVI 4 283 1957
13 *Noe M Ziegler G & Herrera S* Late result of tendon transplantations to quadriceps Revista Medica de Chile Santiago 76/11 674–679 1948
14 *Canalell-Carafi J & Barraquer Bordas L* Resultas del la plastic du quadriceps dans la poliomyelite Acta Orthop Belg 21/4 241–251 1955
15 *Yount C C* An Operation to improve Function in Quadriceps Paralysis J Bone and Joint Surg 20 314 1938

FROM THE ORTHOPAEDIC HOSPITAL OF THE INVALID FOUNDATION HELSINGFORS HEAD A LANGENSKIÖLD M D

COALITIO CALCANEO NAVICULARIS AND CALCANEUS SECUNDARIUS

A clinical and radiographic study of twenty three patients

By

Henrik V A Heikel M D

DEFINITION

In the skeleton of the normal foot the calcaneus and the naviculare are separated by a 5 to 10 mm wide fissure (2) which is filled with ligaments and which admits of a certain mobility An abnormally intimate connection between these bones is called *coalitio calcaneo navicularis* This term comprises all variations from a fibrous connection via amphiarthrosis (A) (Fig 1) to a bony bridge which is called synostosis calcaneo navicularis (S) (Fig 2) The *calcaneus secundarius* (CS (Fig 3) is an accessory bone occurring in the space between the calcaneus and the naviculare

Etiology

In human embryos fusion or non division of the cartilage anlage of the calcaneus and the naviculare (8) and beginning ossification of the connecting cartilaginous bridge have been observed Ossification proceeds from the enchondral ossific centre of the calcaneus or the naviculare and signs of narrowing and disappearance of the fissure between the centres have been observed In some cases the cartilaginous bridge has an ossific centre of its own The centre may fuse with the centre in the calcaneus or the naviculare or with both forming a synostosis (3) or it may remain as a free element In the latter case radiographic examination shows an accessory bone the calcaneus secundarius

Independent calcaneo secundaria with joint surfaces have been observed in adults (2) and it has been assumed that they arise from



Fig 1



Fig 2



Fig 3

Fig 1
Amphiarthrosis cal aneo naviculars (No 13 l)

Fig 2
Synostosis calcaneo navicularis (No 4 l)

Fig 3
Calcaneus secundaris (No 18 l)

cartilaginous primordia of their own The assumption is supported by the observation of independent primordia of other accessory bones in embryonic skeletons of the foot (8)

According to other theories coalitio calcaneo-navicularis arises through faulty differentiation and ossification of the navicular fibro-cartilage (2) and the calcaneus secundarius through ossification of the pars calcaneo navicularis of the bifurcate ligament through osteophyte formation (7) traumatic separation of the anterior process of the calcaneus (7) or heterotopic ossification in synovial tags (8)

Incidence

Coalitio calcaneo-navicularis was observed by *Niederecker* (7) in 27 out of 392 operatively treated feet by *Pfitzner* (9) in 4 per cent of an anatomical series and by *Harris & Beath* (3) in 1 out of 3600 conscripts *Hohmann* (5) estimated the incidence at 2 per cent Until 1954 about 100 cases had been described (2)

Synostosis calcaneo navicularis was observed in 2.9 per cent of *Pfitzner*'s series. According to *Brandt* (2) only some 10 radiologically verified certain cases had been published up to 1954. Later *Jack* (6) reported 4 cases, *Immhauser* 1, *Brandt* 2 and *O'Rahilly* 1 case.

It has been stated that calcaneus secundarius occurs in 2 per cent of anatomical series. *Arho* (1) found 7 cases among 716 radiologically examined adult feet.

Clinical features

Coalitio calcaneo navicularis occurs most usually in conjunction with common rigid or spastic flat foot, but also in the absence of any deformity of the foot and even together with pes cavus. Some cases are symptom free. In other cases transient or chronic symptoms such as stiffness and pain occur in connection with spraining of the ankle, usually at the age of 10 to 14. In a third group of cases these symptoms occur spontaneously. Clinically, a limited mobility in the subtalar joint is observed. Either the pain predominates, or the stiffness and deformity of the foot. The degree of deformity and of limitation in mobility is considered proportional to the degree of development of the bony bridge, and consequently is at a maximum in synostosis calcaneonavicularis (6).

Diagnosis

A definitive diagnosis can only be made on the basis of a radiographic examination. Besides the usual lateral picture of the foot this should also comprise a picture made with the medial edge of the foot against the cassette and the sole at an angle of 45 degrees to it (10).

Treatment

Conservative treatment (immobilization, arch supports, heel wedges, possibly repeated manipulations) is recommended. Surgical procedures are postponed until after the age of 10 to 12 years. Resection of the bony bridge with interposition of soft parts (2), arthrodesis of the subtalar joint (3), and the talonavicular joint (and the calcaneocuboideal joint (6) when necessary combined with wedge resection and transposition of the anterior tibial tendon through a channel in the naviculare have been performed. The small number of the cases renders objective evaluation of the end results uncertain.

Own Material

At the Hospital of the Invalid Foundation coalitio calcaneo-navicularis and calcaneus secundarius respectively have been observed during the period 1955 to 1959 in a total of 29 feet in 17 patients and at the surgical department of the General Hospital in Björneborg during 1959 to 1961 in a total of 3 feet in 2 patients Moreover a transitional form between coalitio and the normal condition was observed in 6 feet in 3 patients In one patient a fracture of the anterior process of the calcaneus imitating a true calcaneus secundarius was observed The composition of the material the most important anamnestic data and clinical symptoms are presented in Table 1

The anomaly was bilateral in 16 patients being developed to different degrees on the right and left sides In 6 cases the anomaly was unilateral The age of the patients varied between 10 and 63 years 13 belonging to the age group 10 to 14 years

In patients nos 4 17 and 18 the diagnosis was made incidentally all the others saw a doctor because of symptoms from their feet Twelve feet had been entirely or almost entirely symptom free Only 7 of the patients with bilateral anomaly had experienced discomfort from both feet

The commonest subjective symptom was pain this being almost equally common in amphiarthrosis and in synostosis Its location was most often the sinus tarsi the next commonest site being the talocrural joint Only 3 patients complained of stiffness 4 of swelling and 2 of slight weakness

In patients nos 3 16 and 23 objective examination according to the agreed scheme was only made after the surgical intervention If these are excluded the following facts emerge from the Table 1

1 Marked or clear flatfoot highly limited eversion and/or inversion and lack of ability to supinate the foot when standing upright were almost constant features in synostosis while these symptoms were present in less than 1 case in 2 in amphiarthrosis

2 Pes abductus and heel valgus exceeding 10 were equally frequent being found in about 1 case in 2 in both groups

3 Moderate limitation of plantar flexion and/or dorsal extension were commoner in synostosis than in amphiarthrosis

4 Spasticity of the peroneal muscles was observed in only 3 cases of synostosis Tenderness on palpation was inconstant in regard to both frequency and location A differential diagnosis between amphi

T…
Symptoms and Sig…

Anom ly	Case no (r = right l = left)	Sex (M = male F = female)	Age (years)	Duration of symptoms: < 1 year	Duration of symptoms: > 1 year	Provoked by trauma	Pain: Initial	Pain: During walk	Pain: After exertion	Pain: At sinus tarsi	Pain: Other sites	Functional disturbance	Other symptoms	Talipes: Adductus	Talipes: Cavus	Talipes: Valgus	Talipes: Planus	f lat…	…10…	…
S	1 r	M	17	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	+	
S	1 l			–	+	–	+	–	+	+	–	–	–	–	–	–	+	+	+	
S	2 r	M	21	–	+	–	–	+	+	+	–	–	–	–	–	+	+	+	+	–
S	2 l			–	+	–	–	+	+	+	–	–	st	–	–	+	+	+	+	( )
S	3 l	M	13	–	+	–	+	+	–	–	cr	–	sw	–	–	–	+	–	–	–
S	4 l	M	19	–	–	–	–	–	–	–	–	–	–	–	–	+	+	+	+	(–)
S	5 r	F	12	–	+	–	+	–	–	–	t	+	sw	–	–	–	+	+	–	
S	6 r	M	14	+	–	–	–	–	+	+	–	–	–	–	–	+	+	+	+	(–)
A	5 l	F	12	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	
A	6 l	M	14	–	–	–	–	–	–	–	–	–	–	–	–	+	+	+	+	
A	7 r	F	11	–	+	–	–	–	–	–	cr	–	d	–	–	–	–	–	–	
A	7 l			–	+	–	–	–	–	–	cr	–	d	–	–	–	–	–	–	
A	8 r	M	11	+	–	–	+	–	–	–	tn	v	–	–	–	+	+	–	+	
A	8 l			+	–	–	+	–	–	–	tn	v	–	–	–	+	+	–	–	
A	9 r	M	12	–	+	–	–	–	+	–	mt	–	–	–	–	+	–	+	+	
A	9 l			–	+	–	–	–	+	–	mt	–	–	–	–	+	–	+	–	
A	10 r	F	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	
A	10 l			+	–	+	+	+	–	–	fm	+	sw	–	–	+	+	+	+	(+)
A	11 r	M	13	+	–	+	+	–	–	+	tm	–	sw	–	–	+	+	+	–	
A	11 l			+	–	+	+	–	–	+	tm	–	sw	–	–	+	+	+	–	
A	12 r	M	16	–	a	+	–	–	–	+	–	st	pi	+	+	–	–	+	+	
A	12 l			–	a	–	–	–	–	–	–	st	–	+	+	–	–	–	+	
A	13 r	M	37	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
A	13 l			–	+	+	–	–	+	–	fm	st	–	–	–	+	+	+	+	
A	14 r	F	63	–	+	–	–	+	–	+	–	–	M	–	–	–	+	–	–	
A	14 l			–	+	–	–	+	–	+	–	–	–	–	–	–	+	–	–	
	15 r	M	12	–	+	–	+	–	–	–	cr	+	l	–	–	+	+	–	+	
	16 l	M	14	–	+	–	–	+	–	+	–	–	–	–	–	–	–	–	+	
)	17 l	F	10	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	
S	18 r	M	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(+)
S	18 l			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(+)
CS	19 l	M	45	+	–	+	–	+	–	–	cr	–	–	–	–	–	–	–	–	
r	20 r	F	10	–	+	–	–	+	+	–	mv	–	–	–	–	+	+	+	–	
r	20 l			–	–	–	–	–	–	–	–	–	–	–	–	+	+	+	–	–
r	21 r	F	12	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
r	21 l			+	–	–	+	+	–	–	–	–	M	–	–	–	–	–	–	
r	22 r	F	26	+	–	–	–	–	+	+	mv	–	–	–	–	–	+	–	–	–
r	22 l			–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
CS)	23 l	M	39	–	+	+	–	+	+	–	–	–	–	–	–	–	+	–	–	

…xplanation of abbreviations A = amphiarthrosis a = always cr = at talocrural joint (…
…nalleolus l = limp M = symptoms of Mortons neuralgia mt = in the metatarsal region…
…c = at the scar st = stiffness sw = swelling t = at tarsal region tm = at tip of t…
…ng and walking

nic illy Examined Cases

h d n ob l ts f t				T ndern s			
i n	E on		al illity to stg l nts f ot hen vt : ll g				R m k
3 9	0 10	10		at l us ta ls	l ll r lt	n nl m	
	+	−	+	−	−	−	earlier treated for cong clubfc ot
	+	−	+	−	−	−	earlier treated for cong clubfoot
	−	+	+	+	−	+	stands on his toes onl with flexed knees
	−	+	+	+	−	+	
	+	−	+	+	t	−	(Pcstoperative status) Bilat insufficiency of glutei and gastrochnemii
+	−	+	+	+	−	−	Luxatio cong coxae sin
+	−	−	(+)	−	−	−	
	−	+	(+)	+	−	+	
+		−	(+)	−	−	−	
	−	+	(+)	−	−	−	
	−	+		−	−	−	
	−	−	−	−		−	
	−	−	−	−	fm	−	
	−	−	−	−	fm	−	
−	−	+	−	−	−	−	earlier had calcaneus varus
−	−	+		−	−	−	earlier had calcaneus varus
	−	−		−	−	−	
	−	+		−	−	−	
+	−	+	(+)	+	−	−	
−	−	+	(+)	+	−	−	
	−	+	(+)	−	−	−	
	−	+	(+)	−	−	−	
	−	−		−	−	−	
	+	−	(+)	−	−	−	has had no relief of the s mptom b arch support
−	−	+		+	−	−	treated elsewhere for "rheumatism" with injections of f rmic acid
		+		+	−	−	
	+	−	−	+	−	−	
	−	+	−	+	−	−	(postoperative status)
+			−	−	−	−	remitted for examination b the schocl physician
	−	+	−	−	−	−	treated for fracture of basis metatarsali V
		−	−	−	−	−	
		−		−	−	−	years age sprained his ancle but nct examined b a dcctor
	−	−		−	−	−	
		−	−			−	
		+	−	−	−	−	
		−	−	+	−	−	
		−	(+)		m\	−	
	−	−		−	−	−	
−		+			c		(postcperative status) Fracture f anterior process of calcaneu

cal aneu ecundarius d — repeated small d storsions of the ankle fm — in fr nt of the tibial — at ba c f V metatar l b ne pi — pains when walking on an inclined plane S — synostosis m lle lu tn — at tal navicular joint tr — transient case and v — varus tendency when stand



Fig 4
Amphiarthrosis calcaneo navicularis et cuboideo navicularis (No 10 l)

arthrosis and calcaneus secundarius and the transitional form to normal conditions could not be clinically ascertained

Radiographic observations

The bony bridge in synostosis was always at least 1 cm wide while in amphiarthrosis the width of the joint surfaces was less than 0.5 cm in 6 cases Repeated radiographic examinations showed that in one case the width of the joint surfaces increased proportionally with the growth of the skeleton To be able clearly to demonstrate the absence or presence of a fissure between the calcaneus and the naviculare or between these and the os calcaneus secundarius it was often necessary to take several radiograms varying the position of the foot and the direction of the central ray

The differential diagnosis between calcaneus secundarius and a fracture of the anterior process of the calcaneum may be uncertain In case no 18 l (Fig 3) there had been no traumate the foot was symptomless The ventral joint surfaces of the bone between calcaneus and naviculare formed a step and the structure of the bone was cloudy as it was in case no 9 r (Fig 5 D) This case was considered as one of a true calcaneus secundarius In case no 23 l the symptoms were provoked by a severe hyperflexion trauma The joint surfaces formed an unbroken curved line and the bony structure of the bone between calcaneus and naviculare was well developed This case was considered as one of fracture of the anterior process of the calcaneus

In more than half the cases equally often in synostosis and in amphiarthrosis beginning or moderate arthrosis was observed in the talo-



Fig. 5

Os calcaneus secundarius fusing with calcaneus and naviculare respectively (No. 9 l = A–C and No. 9 r = D–F. A and D at 11½, B and E at 12 and C and F at 14)

navicular joint, the condition being severe in two of the cases of synostosis (bilaterally in patient no. 2).

Accessory findings were os tibiale externum 6 times (nos. 4 r, 8 r, 8 l, 12 l, 18 r and 22 r), os peronaeum once (no. 8 r), os intermetatarsale once (no. 12 r) and vesalium once (no. 18 r), and splitting into two of one of the sesamoid bones of the great toe 8 times (nos. 12 r, 12 l, 14 r, 14 l, 16 r, 16 l, 21 r and 21 l). Such accessory findings were thus observed twice in feet without other anomalies. Besides a narrow amphiarthrosis between the calcaneus and the naviculare in case 17 l there was also a wide one between the cuboideus and the naviculare (Fig. 4).

In radiograms of patient 9 taken at intervals of about one year from the ages of 11 to 16 years, it was possible to observe how an os calcaneus secundarius on the left side fused with the calcaneus and on the right side with the naviculare (Fig. 5). In patients 6, at the age of 13, bilateral



Fig 6
Development of amphiarthrosis to synostosis (No 6 r A at 13 and B at 14½)

amphiarthrosis was observed but at re examination one and a half years later synostosis was found on the right side (Fig 6)

Treatment

Thirteen patients were given or already had arch supports In cases of synostosis this treatment was without any effect while in other groups considerable relief was achieved in all cases exept three The symptoms of one patient disappeared after a period of rest Five feet in 4 patient were treated surgically

No 2 r and 2 l Owing to persistent pain in the foot which was not relieved by arch supports extra articular subtalar arthrodesis was carried out according to *Grice* At follow up half a year later the patient was subjectively symptom free the position of the feet was improved there was insignificant persisting eversion of the heel and the bony transplant had healed (Fig 7)

No 3 l As it was presumed that the stiffness and tenderness caused by the synostosis was the reason for the stiff gait of the patient and that through inactivity they had indirectly produced weakness of the glutei and the triceps surae resection of the bony bridge with interposition of a flap of soft tissue was carried out The joint capsule was found to be thickened histological examination demonstrating signs of unspecific arthritis At follow up one year later the status of the patient both subjectively and objectively was unchanged Radiographic examination revealed calcareous deposits at the site of the resected bony bridge (Fig 8)

No 15 l Owing to pain at plantar flexion and inversion after strain which could not be alleviated with arch supports the amphiarthrosis (Fig 9) of about 1 cm was resected and a soft tissue flap interposi



Fig 7

Synostosis calcaneo navicularis treated by extra articular arthrodesis a m Cace status ½ year postoperatively (No 2 r)



Fig 8

Synostosis calcaneo navicular treated by resection of the bony bridge A before and B 1 year after the resection Note the calcaneous deposits at the site of the former bridge in B (No 3 1)



Fig 9

Amphiarthrosis calcaneo navicularis treated with resection of the bridge Radiograph of the resected specimen (No 16 1)



Fig 10

"False os calcaneus secundarius originating from fractured anterior process of the calcaneus A and B after the initial trauma C preoperatively D at resection (interpreted as showing that the fragment has been removed) and F one year later showing the fragment still in place (No 23 I)

tioned At follow up one and a half years later the patient was subjectively symptom free and the mobility of the foot normal with the exception of slight limitation of eversion

No 23 I Under the diagnosis fracture of the anterior process of the calcaneus the patient had been treated elsewhere with immobilization and arch supports without subjective alleviation of the symptoms Injection of Hydrocortisone between the calcaneus and naviculare gave no relief At operation a piece of bone was removed which at radiographic control (also postoperatively) was identified as the primarily observed fragment and a flap of soft tissue was interpositioned At follow up one year later the patient stated that symptoms still occurred

after heavy work but that otherwise arch supports gave sufficient relief Radiographic examination showed that the primarily observed fragment still persisted (Fig 10)

CONCLUSIONS

The present study corroborates previous observations on subjective symptoms and objective findings in this anomaly of the skeleton of the foot An almost constant phenomenon in synostosis was inability to supinate the foot when standing upright In amphiarthrosis the foot may preserve a high degree of mobility even when the joint surfaces are wide and the joint space narrow

The observations in cases 6 and 9 argue in favour of the assumption of an undivided cartilaginous primordium of the calcaneus and the naviculare in coalitio calcaneo navicularis In none of the observed cases does the shape of the connection or its topographical site lend support to the suggestion that it originates through ossification of the navicular fibrocartilage In case 23 a condition resembling os calcaneus secundarius may have occurred through fracture of the anterior process of the calcaneus followed by pseudoarthrosis

Treatment of synostosis with arch supports seems futile while in mild cases of coalitio it may be adequate Early radical resection in amphiarthrosis may result in freedom from symptoms (no 16) No certain conclusions can be drawn on the basis of cases 3 and 23 in the former the picture was complicated by an unspecific arthritis and in the latter the operation contemplated was not carried out Case 2 shows that as long as marked arthrosis of the talonavicular and calcaneo cuboideal joints do not demand triple arthrodesis extra articular sub talar arthrodesis as described by *Grice* may give good results in synostosis

SUMMARY

A series of altogether 31 cases of coalitio calcaneo navicularis or calcaneus secundarius and one case of false calcaneus secundarius is reported in 5 of which surgical treatment was given Treatment with arch supports may be adequate in mild cases of coalitio but seems futile in synostosis Early resection in amphiarthrosis may give good results as extra articular subtalar arthrodesis may do in cases of synostosis without marked deforming arthrosis Triple arthrodesis is probably the most adequate treatment in cases with pronounced arthrosis

RÉSUMÉ

Rapport sur une série qui compte en tout 31 cas de coalitio calcaneo-navicularis ou calcaneus secundarius et un cas de faux calcaneus secundarius. Un traitement chirurgical a été appliqué dans 5 de ces cas. Le traitement au moyen de supports courbes peut être approprié dans les cas bénins de coalitio, mais peut paraître futile lorsqu'il s'agit de synostose. Une résection précoce de l'amphiarthrose peut donner de bons résultats, également l'arthrodèse subtalar extra articulare dans les cas de synotose sans arthrose déformante marquée. Une tripl arthrodèse est probablement le traitement le plus approprié dans les cas chez lesquels il y a arthrose prononcée.

ZUSAMMENFASSUNG

Über eine Reihenfolge von 31 Fällen von Coalitio calceneo-navicularis oder calcaneus secundarius und einen Fall von falschem calceneus secundarius wird berichtet. Bei fünf von diesen Fällen wurde eine chirurgische Behandlung vorgenommen. Die Behandlung mit Plattfusseinlagen kann in milden Fällen von Coalitio ausreichend sein, scheint jedoch bei Synostosen vergeblich zu sein. Frühzeitige Resektion kann bei Amphiarthrosen gute Ergebnisse zeitigen. Ebenso kann man mit der extra artikulären subtalaren Arthrodese in Fällen von Synostosis ohne ausgesprochene Arthrosis deformans gute Resultate erzielen. Triple Arthrodese ist wahrscheinlich die beste Behandlungsmethode in Fällen mit ausgesprochener Arthrose.

REFERENCES

1. *Arho, O. A.*: Raajojen synnynnäiset luut röntgenkuvissa. Duodecim *11*: 399, 19[illegible]
2. *Brandt, C.*: Über die Bedeutung und spezielle Diagnostik der Coalitio calcaneo-navicularis. Arch. orthop. Unfall-Chir. *48*: 202, 1956.
3. *Harris, R. I. & Beath, Th.*: Etiology of Peroneal Spastic Flat Foot. J. Bone Jt. Surg. *30B*: 624, 1948.
4. *Herschel, H. & v. Ronnen, J. R.*: The Occurrence of Calcaneonavicular Synostosis in Pes Valgus Contractus. J. Bone Jt. Surg. *32A*: 280, 1950.
5. *Hohmann*: quoted by Niederecker.
6. *Jack, E. A.*: Bone Anomalies of the Tarsus in Relation to "Peroneal Spastic Flat Foot". J. Bone Jt. Surg. *36B*: 530, 1954.
7. *Niederecker, K.*: Pathologische Veränderungen des Fuss skelettes bei Plattfüssen an Hand eines grösseren Operationsmaterials. Z. Orthop. *60*: 97, 1931.
8. *O'Rahilly, R.*: Developmental Deviations in the Carpus and the Tarsus. Clin. Orthop. *10*: 9, 1957.
9. *Pfitzner*: quoted by Brandt.
10. *Sloman, H. C.*: On the Demonstration and Analysis of Calcaneo-navicular Coalition on Roentgen Examination. Acta Radiol. *5*: 304, 1926.

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GRADING OF OSTEOPOROSIS IN AUTOPSY SPECIMENS

A New Method

By

OLOV LINDAHL and ÅKE G. H. LINDGREN

Whereas in advanced osteoporosis there is little difficulty in forming a diagnosis by radiography, the mild case is not so easily recognized; by the time the condition can be detected much of the bone has disappeared, the actual amount is put at between 15 and 60 per cent by various workers (3, 6, 8, 12). The lower values apply to small bones with little soft tissue covering, and the higher values to the spinal column and the pelvis. Nor is radiography a reliable method of grading the porosity or of evaluating the changes therein. Moreover, at least in the milder grades of osteoporosis, macroscopic and histologic evaluation of the bone specimen is extremely difficult and purely subjective; one reason for this is that the porosity of spongy bone varies widely throughout the skeleton.

In anthropology it was found that the quotient of weight by volume of various parts of the skeleton decreased significantly with the age of the subject. It was higher for negroes than for whites of the same age. The following average values were obtained for 80 femurs and vertebral bodies (5).

	Negroes		Whites	
	Men	Women	Men	Women
Femur	0.70	0.65	0.63	0.60
Vertebrae	0.48	0.46	0.41	0.38

Density or true density (weight/volume) is a familiar physical constant and the term applies to materials of uniform density. *Apparent density* is a similar constant used of porous materials such as plastic

sponge It too is the quotient of weight by volume but unlike the true density the small spaces in the material are included in the volume

For compact bone the true and apparent densities are identical and the values are the same for osteoporotic as for normal bone In the case of spongy bone however the true density is the same for the normal and osteoporotic tissue and equal to that for compact bone The apparent density is considerably lower for spongy bone and it decreases further as the porosity increases Determination of the apparent density of spongy bone would thus seem to be a highly reliable test for osteoporosis and at the same time to provide a suitable means of grading the disease In osteoporosis there is probably a change in the thickness and amount of compact bone but this cannot be determined by the methods discussed here because there is no difference in the apparent density for the normal and pathologically altered tissue No systematic investigation seems to have been made of the apparent density of spongy bone with a comparison between normal subjects and osteoporotics nor are there data on the normal ranges of variation The present study was accordingly undertaken with a view to determining the apparent density of spongy bone at various ages and examining the different grades of osteoporosis

MATERIAL

The specimens of bone were taken from the lumbar spine and the upper part of the tibia of 60 autopsy cases of various ages As far as possible each decade was represented by 8 subjects 4 of each sex and a selection was made of persons who had died without prolonged confinement to bed At St Goran s Hospital where there are about 1000 beds and where some 600 autopsies are performed every year the autopsy cases are predominantly of the higher age groups Since ages below 40 years were represented to but a small extent during the two years covered by the investigation (1958–59) the material was supplemented with specimens obtained at medico legal autopsies where the cause of death was usually external violence or occasionally poisonin

The age and sex distributions of the material are given in Table 1 Women were slightly in the minority in the lower age groups Most of the subjects below 40 years of age were medico legal cases (Table 2) The younger age groups therefore consisted chiefly of physically healthy persons whereas the older subjects had suffered from and died from disease For this reason and because the number of subjects in each

group was too small the material so obtained cannot be regarded as statistically representative of the general population in respect of the condition of the bone A more representative series was not however available

TABLE 1

Distribution of subjects with respect to sex and age

Age group	14-19	20-29	30-39	40-49	50-59	60-69	70-79	80-91	Total
Women	4	1	2	4	3	3	5	7	29
Men	3	6	5	3	3	3	4	4	31
Total	7	7	7	7	6	6	9	11	60

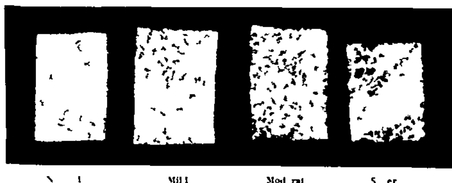
TABLE 2

Distribution of subjects with respect to age group and type of autopsy (clinical or medico legal)

Age group	14-19	20-29	30-39	40-49	50-59	60-69	70-79	80-91	Total
Medico legal	6	7	3	0	0	0	0	0	16
Clinical	1	0	4	7	6	6	9	11	44

METHODS

Macroscopic evaluation —The macroscopic grading of porosity was performed on a cut surface of each bone specimen The following four degree scale was applied according to the degree of osteoporosis normal mild moderate severe (Fig 1)



Normal Mild Moderate Severe

Fig 1

Specimens of spongy bone from lumbar vertebrae with different grades of porosity classified according to four degree scale of osteoporosis

spongy It too is the quotient of weight by volume but unlike the true density the small spaces in the material are included in the volume For compact bone the true and apparent densities are identical and the values are the same for osteoporotic as for normal bone In the case of spongy bone however the true density is the same for the normal and osteoporotic tissue and equal to that for compact bone The apparent density is considerably lower for spongy bone and it decreases further as the porosity increases Determination of the apparent density of spongy bone would thus seem to be a highly reliable test for osteoporosis and at the same time to provide a suitable means of grading the disease In osteoporosis there is probably a change in the thickness and amount of compact bone but this cannot be determined by the methods discussed here because there is no difference in the apparent density for the normal and pathologically altered tissue No systematic investigation seems to have been made of the apparent density of spongy bone with a comparison between normal subjects and osteoporotics nor are there data on the normal ranges of variation The present study was accordingly undertaken with a view to determining the apparent density of spongy bone at various ages and examining the different grades of osteoporosis

MATERIAL

The specimens of bone were taken from the lumbar spine and the upper part of the tibia of 60 autopsy cases of various ages As far as possible each decade was represented by 8 subjects 4 of each sex and a selection was made of persons who had died without prolonged confinement to bed At St Göran s Hospital where there are about 1000 beds and where some 600 autopsies are performed every year the autopsy cases are predominantly of the higher age groups Since ages below 40 years were represented to but a small extent during the two years covered by the investigation (1958–59) the material was supplemented with specimens obtained at medico legal autopsies where the cause of death was usually external violence or occasionally poisoning

The age and sex distributions of the material are given in Table 1 Women were slightly in the minority in the lower age groups Most of the subjects below 40 years of age were medico legal cases (Table 2) The younger age groups therefore consisted chiefly of physically healthy persons whereas the older subjects had suffered from and died from disease For this reason and because the number of subjects in each

xylene dried again at 100 C for 3 days and weighed The apparent density was then determined by dividing the weight by the volume It was thus expressed in milligrammes per cubic millimetre

Statistics—The usual statistical methods were used for calculating the mean range standard error and regression coefficient The formulae and methods are reported elsewhere (10)

RESULTS

Macroscopic examination

Osteoporosis visible to the naked eye did not appear until after 50 years of age it was distinctly more marked among the women (Table 3 Fig 3)

Microscopic examination

No attempt was made to grade the osteoporosis in the sections under the microscope (see *Relative area of bone*) The sections were examined only for the presence of pathologic alterations In no case were osteomalacia or tumours found

Relative area of bone

The mean relative area of bone in different age groups decreased with age but this reduction was not regular (Table 4 Fig 4) There was no difference between the sexes as there was in the case of the gross examination

There was a significant correlation between age and relative area of bone (regression coefficient -0.131 ± 0.047 $0.001 < P < 0.01$) The graphic representation of the correlation between apparent density and

TABLE 3

Distribution of subjects according to degree of osteoporosis evaluated by gross examination

Age group	14-19		20-29		30-39		40-49		50-59		60-69		70-79		80-91		Total		
Sex	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀ ♂
Degree of osteoporosis																			
None	4	3	2	5	2	5	4	3	0	3	0	0	0	0	0	0	11	19	30
Mild	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	1	2	3
Moderate	0	0	0	0	0	0	0	0	2	0	0	3	3	2	0	2	5	7	12
Severe	0	0	0	0	0	0	0	0	0	0	3	0	2	0	7	2	12	2	14

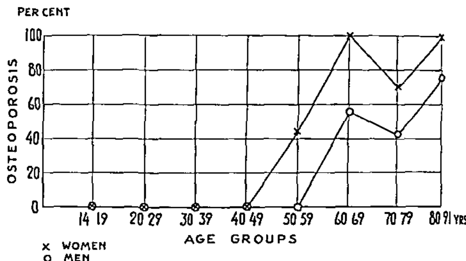


Fig 3

Variation of number of cases of osteoporosis with respect to age group The degree of osteoporosis was evaluated by gross examination The percentage of subjects with moderate osteoporosis has been divided by 2 and that for mild osteoporosis by 3 the percentages in each age group have then been added Thus 100 per cent osteoporosis corresponds to the situation where all the subjects in the age group have severe osteoporosis

relative area of bone shows a wide scattering of the values (Fig 5) The correlation was almost significant (regression coefficient $+0.245 \pm 0.119$ $0.01 < P < 0.05$)

Apparent density

Variation between lumbar vertebrae of the subject —One to four vertebrae were examined in each of 60 subjects in 7 subjects one vertebra in 8 two in 38 three and in 7 subjects four a total of 165 vertebrae In only 9 per cent of the subjects did the apparent density of the

TABLE 4

Mean relative area of bone from tibia in the various age groups (expressed as a percentage of the total area of section)

Age group	14-19	20-29	30-39	40-49	50-59	60-69	70-79	80-91
Mean area of bone								
Female	26	23	26	22	16	14	13	20
Male	29	21	26	22	12	21	20	17
Both sexes	27	21	26	22	14	18	16	18

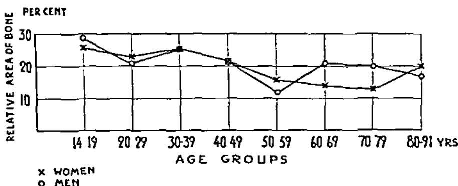


Fig 4

Variation of mean relative area of bone in the tibia section with respect to age group

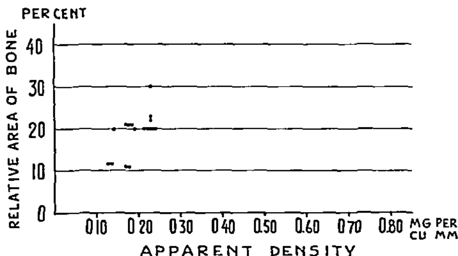


Fig 5

Relationship between apparent density and relative area of spongy bone from the tibia Each dot represents one subject

TABLE 5

Distribution of subjects according to difference in apparent density between vertebrae of the same subject

Difference (mg cu mm)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
No of subjects										
2 vertebrae	2	3	1	1	1	0	0	0	0	0
3 vertebrae	4	11	7	6	6	0	1	0	1	2
4 vertebrae	0	4	2	0	0	0	1	0	0	0

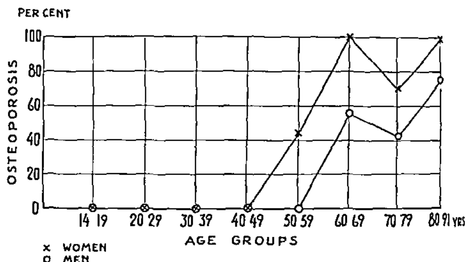


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Male	29	21	26	22	12	21	20	17
Both sexes	27	21	26	22	14	18	16	18

of the regression line for the values higher than 0 20 is steeper than for lower values (These two groups above and below 0 20 mg per cu mm are later defined as normal and osteoporotic respectively) This may be interpreted as showing that the apparent density of the tibia did not decrease as rapidly as that of the vertebrae in cases of osteoporosis This is also suggested by the graphical representation of the relationship in Fig 7

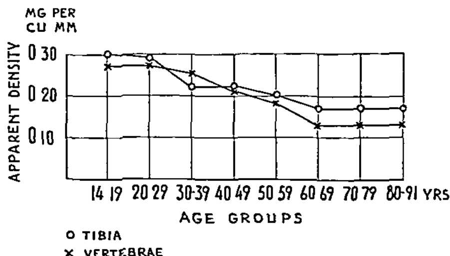


Fig 7
Variation of mean apparent density of vertebrae and tibia with respect to age group Values for men and women combined

Variation with age—The maximum mean apparent density was found in the 14–19 year age group there was then a gradual decrease until 60–69 years after which the values remained constant The variation was parallel for the tibia and vertebrae up to the 50–59 year group after which the mean values for the vertebrae were slightly lower Analysis of the individual values for the vertebrae from subjects below 60 years (Fig 8) showed a negative and highly significant regression for apparent density on age ($P<0\ 001$) The same trend was found for the tibia (Fig 9) except that in the case of the subjects above 60 years the values for these specimens were slightly higher than those for the vertebrae Here too the negative regression was highly significant For subjects above 60 years the means were significantly higher for the tibia than for the vertebrae ($P<0\ 001$) but there was a large variation between individuals (Figs 8 and 9)

involved the bone in the extremities remaining unaltered (2) The present study however showed a gradual increase in porosity with age for both vertebrae and tibia though the effect at advanced age was more marked in the vertebrae It seems to be generally held that osteoporosis is a disease that attacks certain persons while the vast majority are unaffected by it This view is not borne out however by the gradual reduction in the porosity of the tibia and vertebrae with age from 20 years upwards observed in this study in fact it would seem that the weakening of the spongy bone with age is on an average a more or less normal process The fact that this process has not been noted earlier is attributable to the absence hitherto of any accurate method of gradation for radiography does not provide a reliable diagnosis until the process is rather advanced Moreover the discovery of the disease by radiography is of course dependent on the patient s consulting a physician In view of the findings of this investigation the considerably higher incidence of osteoporosis among women that is reported in the literature may not as is commonly held be due to deficient excretion of female hormones after the climacteric Since the apparent density has been shown to be consistently lower for women than for men a diagnosis of osteoporosis must have been made more frequently and earlier for women by a method that does not disclose the disease until it is fairly advanced A division of cases of osteoporosis into post climacteric and senile implies a correlation with time rather than with cause and such a classification is not supported by the results of this study

To examine the validity of the widely held view that muscular disuse can give rise to osteoporosis autopsy specimens were obtained from subjects that had been confined to bed for long periods owing to neurologic disorders In three cases where the period was more than 5 years the apparent density was extraordinarily low

		Apparent density (mg mm^3)	
	Age	Tibia	Vertebrae
Case 1	29	0 10	0 11
Case 2	32	0 13	0 13
Case 3	43	0 11	0 13

The gradual development of osteoporosis from the age of 20 years the more marked porosity among women the large individual variation and the severity of the condition after long muscular disuse in

dicate that inactivity is an important factor in the development of osteoporosis In practice there will of course be other contributory factors such as depletion of calcium and cortisone therapy

DEFINITION OF OSTEOPOROSIS

There is a certain variation among the definitions of osteoporosis but common to all is the view that this condition includes a deficiency of bone substance owing to defective formation of matrix The ash content calcium content and bone density are normal (1 11)

Any definition of osteoporosis should enable one to decide whether or not the condition is present it would seem that none of the current definitions satisfies this requirement Theoretically defective matrix formation may be regarded as a definition of osteoporosis in practice however it is difficult to ascertain whether there is such a deficiency for there are no normal values for the content of bone matrix in the body nor are there methods of ascertaining this quantity in any particular case The problem is in fact difficult to solve Since the true density of osteoporotic bone is the same as that of normal bone it should be possible to determine the amount of bone matrix from the total weight of the whole skeleton exclusive of soft tissues This must be divided by the weight of the body The quotient then obtained is rather unreliable owing to the different proportions of fat and muscle

The statement included in most definitions of osteoporosis that the disease is due to defective formation of the bone matrix is open to criticism for this is no more than a hypothesis Such statements tend to set development on wrong paths since we are at present unaware of the cause of osteoporosis Of the four theories that are most widely advanced—disturbance of protein metabolism chronic deficiency of calcium muscular disuse and abnormally low secretion of oestrogens — only the first is consistent with this definition-cum hypothesis

The mean apparent density of the tibia specimens of the 14–29 year groups which may be regarded as largely normal was 0 28 mg per cu mm for 5 women and 0 31 for 9 men with a mean of 0 30 for the whole group of 14 subjects According to the available information all these patients had been healthy and death was due to sudden external violence poisoning or acute illness The bone was both grossly and microscopically normal The variation in the apparent density for these cases was large (0 17 0 20 0 22 0 24 0 24 0 25 0 26 0 28 0 28 0 30 0 30 0 33 0 40 0 76) but most of the values lay within the the range 0 20–

0.30. Variations within the normal limits would be due to for instance differences in physical activity. The extreme value 0.76 was for a powerfully built 22-year-old man.

For the 11 tibia specimens that were classed by gross examination as severely osteoporotic the mean apparent density was 0.12 mg per cu. mm (range 0.09–0.18). The corresponding figure for these 13 vertebrae specimens was 0.11 mg per cu. mm (range 0.07–0.19). On the basis of these figures, it is reasonable to define osteoporosis as a decrease to below 0.20 mg per cu. mm in the apparent density of the spongy bone in the upper end of the tibia, provided that microscopic examination discloses no pathologic condition of the bone.

Essentially the same definition might apply to the spongy bone of the vertebrae, but it is not so easy to obtain specimens from this region in the living subjects.

In one case where a value of 0.07 was recorded for a vertebra specimen, and in others with values of about 0.10 it appeared from the gross examination that further porosity would result in compression of the vertebral bone so that its apparent density would then increase again.

An apparent density of, for instance, 0.15 mg per cu. mm might not seem low enough to deserve attention, but when converted to a percentage with 0.19 as 100 per cent and 0.09 as 0 per cent, this value is seen to correspond to 60 per cent of the normal porosity—a figure that perhaps gives a more realistic impression of the degree of osteoporosis.

SUMMARY

The apparent density of spongy bone in osteoporosis would seem to provide an exact measure of the degree of osteoporosis. To examine the validity of this supposition a study was made of autopsy specimens of tibia and vertebrae obtained from 60 subjects of ages ranging from 14 to 91 years. Beside gross and microscopic evaluations, the relative bone area was determined in sections prepared from the specimens. None of these methods was found to be accurate enough to permit of a reliable grading of osteoporosis in the individual case.

The average apparent density—or weight of unit volume—of spongy bone for various age classes ranged from 0.33 to 0.11 mg per cu. mm and extreme individual values of 0.76 and 0.07 were recorded. The mean apparent density was a maximum in the 14–19 year age group and decreased steadily to 60–70 years. The variation was largely parallel for the tibia and vertebrae specimens. The apparent density was significant

ly lower for women The reduction with age was essentially the same for men and women

On the basis of these results it would seem reasonable to define osteoporosis as a reduction in the apparent density of the tibia to below 0 20 provided that the microscopic examination discloses no pathologic alterations

RESUME

La densite apparente de l os dans l osteoporose pourrait sembler fournir une mesure exacte du degre d osteoporose Afin de controler la validite de cette supposition une etude a ete faite en procedant a l autopsie de specimens de tibia et de vertebre provenant de 60 sujets dont l age variait entre 14 et 91 ans En plus des examens d ensemble et microscopiques la surface relative des os a ete determinee en preparant des sections des specimens

Aucune de ces methodes n a ete consideree comme suffisamment exacte pour permettre d evaluer le juste degre d osteoporose dans un cas individuel

La densité moyenne apparante – ou le poids par unite de volume – du tissu spongieux dans différentes classes d ages varie entre 0 33 et 0 11 mg par mm³ et les valeurs individuelles extremes de 0 76 a 0 07 ont ete enregistrees La densite moyenne apparente atteint un maximum dans le groupe d age entre 14 et 19 cas pour decroitre constamment jusqu a 60–70 ans La variation est largement parallèle pour les specimens de tibia et de vertebre La densite apparente est nettement plus basse chez les femmes La reduction de la densite avec l age est essentiellement la meme chez les hommes que chez les femmes

Sur la base de ces resultats il parait raisonnable de definir l osteoporose comme la reduction de la densite apparente du tibia a moins de 0 20 a condition que l examen microscopique ne revele pas d alterations pathologiques

ZUSAMMENFASSUNG

Die augenscheinliche Dichte des Knochens bei der Osteoporose scheint einen genauen Masstab fur den Grad der Osteoporose zu ergeben Um die Gültigkeit dieser Vermutung festzustellen wurde eine Untersuchung an Autopsiepräparaten von Tibia und Wirbeln die von 60 Individuen im Alter von 14 bis 91 Jahren stammten vorgenommen Abgesehen von grober und mikroskopischer Bewertung wurde die relative Knochenfläche in Schnitten die von den Präparaten zubereitet waren bestimmt

Keine dieser Methoden erwies sich genau genug um eine verlässliche Schätzung der Osteoporose im einzelnen Falle zu gestatten Die durchschnittliche scheinbare Dichte – oder Gewicht des Einheitsvolumens – für die Spongiosa verschiedener Altersklassen reichte von 0 33 bis 0 11 mg mm³ und extreme individuelle Werte von 0 76 bis 0 07 wurden verzeichnet Die scheinbare Durchschnittsdichte zeigte ein Maximum in der 14–19 Jahre Altersgruppe und nahm fortlaufend bis zu 60–70 Jahren ab Die Verschiedenheit lief im Grossen und Ganzen parallel in den Tibia und Wirbelpräparaten Die augenscheinliche Dichte war deutlich niedriger beim weiblichen Geschlecht Die Herabsetzung mit dem Alter war im wesentlichen die gleiche bei Frauen und Männern

Auf Grund dieser Ergebnisse würde es angebracht Osteoporose als eine Verminderung der scheinbaren Dichte der Tibia unter 0,20 zu definieren vorausgesetzt dass die mikroskopische Untersuchung keine pathologischen Veränderungen aufzeigt

REFERENCES

1 *Agna J Knowles H & Alversson P* J Clin Invest 37 1357–1361 1958
2 *Albright F & Reifenstein E* The Parathyroid Glands and Metabolic Bone Disease The Williams & Wilkins Company Baltimore 1948 pp 145–204
3 *Ardran G* Brit J Radiol 24 107 115 1951
4 *Ball J* Diseases of Bone Recent Advances in Pathology Edited by C V Harrison Ed 7 J & A Churchill Ltd., London 1960
5 *Broman C Trotter M & Peterson R* Am J Phys Antropol 16 197 211 1958
6 *Fusi G* Radiol Clin 22 123 131 1953
7 *Lachman A* Radiology 26 165–174 1936
8 *Landorff C A* Acta chir Scand. Suppl 71 1942
9 *Lindahl O* Acta orthop Scand 29 160–163 1960
10 *Lindahl O* Acta physiol Scand. Suppl 179 51 1961
11 *Rutinhauser F & Maulbetsch A* Beitr z. path Anat u z allg Path 94 337 344 1934
12 *Sante L R* Principles of Roentgenological Interpretation Revised ed. 10 Edward Brother Inc., Michigan 195 p 552

FROM THE DEPARTMENT OF NEUROLOGICAL SURGERY
UNIVERSITY OF LUND SWEDEN

HE SURGICAL TREATMENT OF DYSTONIC TORTICOLLIS

By

N G LUNDBERG and G SVANTESSON

In a previous catamnestic analysis of 50 patients operated upon for ystonic torticollis at the Department of Neurosurgery of the Sera mer Hospital Stockholm (Professor H Olivecrona) during the years 926–1944 the results of intradural section of ventral cervical roots nd or extradural section of the accessory nerve were presented (*Lund erg* 1946) This analysis suggested certain modifications of the stan ard procedure These modifications were later applied to 22 cases eated at the Department of Neurosurgery Lund in 1946–1957 The tter cases have been carefully followed up by questionnaires and ersonal examination

The main purpose of the present investigation was to assess on the asis of two relatively large series the end results of a surgical tech ique hitherto generally used in the treatment of torticollis and se ondly to estimate the value of certain modifications used in the second eries

PATHOGENETIC VIEWS

The condition generally known as torticollis spastica is characterized by a more r less continuous irregular activity of the neck musculature giving rise to com ul ive movements or posture of the head In addition various types of trem r are t uncommon It is not correct to call this condition spasticity dystonia being a n re adequate term (see *Her & Glaser* 1949) The activity usually occurs when he head is held upright and usually disappears when the patient is l ing It is ccentuated considerably by mental stress and generally reduced if the patient upports the chin with the hand

The eti logy of torticollis can only be briefly discussed here The reader is re rred to the extensive survey of *Patterson & Little* (1943) In their report of 103 ase of torticollis *Patterson & Little* expressed the view that torticollis is rarely sychogenic and that many ca es regarded as being of functional origin do not t f the definition of spa modic torticolli "An involuntary hyperkinesis mani fe ting itself b mobile tonic or clonic spasm of the neck musculature and pro du ing a more or les stereotyped deviation f the head into an abnormal position

the chin being rotated to one side or the head bent directly forward (antecollis) or backward (retrocollis)" It is well known that mental strain and tension can contribute considerably to the symptoms of torticollis This is compatible with *Foerster's* (1921) opinion that lesions of the extrapyramidal system are often asymptomatic until symptoms are precipitated by mental or other factors

Folt et al (1959) described 7 cases of torticollis in *Macaca Mulatta* produced by stereotactic lesions placed paramedially in the brain stem. All the lesions were placed in the middle of the tegmentum mesencephali at the level of the decussatio brachii conjunctivi involving the brachium conjunctivum fasciculus longitudinalis medialis and formatio reticularis medialis Lesions in the last mentioned structure were regarded as the most important in the causation of torticollis It appears that the torticollis produced by *Folt* closely resembled that seen in human beings, in contrast to the picture produced by lesions of the brain stem of monkeys by *Kemberling et al* (1952) It is noteworthy that the dystonic activity often disappeared when the animals were left alone but could be provoked by measures making the animals restless or uneasy In addition the activity decreased when the animals had become accustomed to a situation that had formerly annoyed them, but increased as soon as they were irritated by new measures

REVIEW OF THERAPEUTIC METHODS

1 *Myotomy* Myotomy was used as early as 1641 by the German *Isaac Minnius* and was recommended later by *Kocher Mikulic* and *de Quervain* at the end of the nineteenth century (*de Quervain* 1896) This method has since been abandoned because it does not control the dystonic activity

2 *Division of peripheral nerves* Division of the accessory nerve was first described in 1834 by *Bujalski* (according to *Patterson & Little* 1943) *Keen* (1891) severed the posterior rami of the three uppermost cervical segments bilateral *Finney & Hughson* (1925) extended this method to include extradural division of the accessory nerve on both sides and improved upon the method of dissecting the nerves

3 *Intradural division of cervical roots* The first operation of this kind was performed in 1902 by *Cushing* He divided the second ventral root on the left side and the corresponding dorsal root on the right (Cushing's comment to *McKenzie's* article 1924) Later occasional reports of unilateral division of roots were published by *Taylor* (1915) *Foerster* (1933) and *McKenzie* (1924) The first to divide several roots on both sides was *Coleman* (1927)

Unilateral division of *dorsal* cervical roots for spasmodic torticollis was first performed by *Taylor* (1915) and was later suggested by *McKenzie* (1924) and *Frazier* (1930) The theoretical background was the work of *Sherrington* who stressed the importance of the afferent impulses for muscular activity Only a few cases treated in this way have been published including one by *Coleman* (1927) *McKenzie* (1955) considered deafferentation useless on the basis of poor results obtained in two cases

Dandy (1930) reported the results of bilateral division of the three uppermost ventral and dorsal roots in 8 cases (see Table 3) He concluded that deafferentation was superfluous and suggested bilateral intradural division of the three uppermost ventral roots as a standard procedure combined if necessary with division of the ac

cessory nerve In addition denervation should in some cases be extended to include the 4th to the 7th cervical segment inclusive by resection of the posterior rami according to Finney s method

After the reports of *Dandy* (1930) and *Olivecrona* (1931) the standard method suggested by *Dandy* has been the one most commonly used *Putnam* (1946) added the proposal that the 4th ventral root could be divided on both sides without impairing respiration

Five recent reports on fairly large series of operations for torticollis deserve mention For a summary of the results the reader is referred to Table 3 Only a few complementary notes will be given here

Adson et al (1946) described 21 cases in which they only divided the accessory nerve with no improvement in 4 improvement in 16 and recover in 1 Intradural section of roots gave partly satisfactory results In some cases these authors found that denervation caused instability of the cervical spine which required stabilisation by vertebro occipital fusion In one case this operation was fatal because the bone transplant slipped and compressed the medulla Two other deaths were recorded one due to ligation of a large spinal artery and one where division of the 4th ventral roots had caused paralysis of the diaphragm which was complicated by pneumonia

Putnam et al (1949) pointed out that their 18 cases had all been previously treated by different conservative methods without or with only insignificant and temporary effect

Poppen & Martinez Niochet (1951) included in their material 19 patients suffering from other neurological diseases besides torticollis particularly dyskinesia of other parts The results were described as poor in 14 cases and satisfactory in 2? One patient died from air embolism Post mortem examination revealed diffuse cortical necrosis a focal lesion in the mesencephalon and destruction of nerve cells in the dentate nuclei

Wycis & Moore (1954) divided the 4th ventral root bilaterally in one case without causing paralysis of the diaphragm They stated that 8 of their patients made a complete recovery and 1 showed considerable improvement The follow up time however appeared to be short

McKenzie (1955) described the anatomy of anastomoses to the first motor root and stressed the importance of not overlooking these anastomoses His result were given as excellent in 10 cases and not quite satisfactory in 2 Of the former group at least 2 patients were completely free of symptoms when seen 2 and 9 years respectively after operation

Tormä & Troupp (1958) followed up 16 of their 29 cases for more than 1 year Two patients out of 18 treated by intradural division of ventral roots died in association with the operation One patient died from a ruptured aneurysm of the posterior communicating artery and the other probabl from an undiagnosed post operative hematoma

As to treatment other than surgical the reader is again referred to *Patterson & Little* (1943) After an exhaustive survey and discussion of the literature on torticollis they compared the results of different methods on the basis of a follow up study of 103 cases They concluded that surgical treatment is superior to other methods

SERIES FROM SERAFIMER HOSPITAL

In 1926–1944 58 patients had been operated upon with extradural division of the accessory nerve and/or intradural division of cervical roots in different combinations (only accessory nerve in 11 unilateral root section in 3 bilateral section of ventral roots in 30 cases bilateral section of ventral and dorsal roots in 6) In 3 cases the 4th ventral root was divided on one side in all the others the operation included only the 3 upper roots The operations claimed no mortality The patients were later reviewed by questionnaires and 50 co-operated The average follow up time was 8 years after the operation (at most 16 years at least 1½ years)

According to the questionnaires the symptoms of torticollis had abated considerably or disappeared in 80 per cent If sequelae ascribable to the operation were included partial or complete improvement was recorded in 66 per cent Of 46 patients in whom the accessory nerve had been divided 46 per cent reported severe or moderate symptoms in the operated shoulder and arm Working capacity was unimpaired in 30 per cent moderately impaired in 46 per cent and 24 per cent of the patients were severely or completely disabled The loss of workin capacity was ascribed partly or entirely to persistent symptoms of torticollis in 31 per cent insufficiency and pain in the musculature of the neck in 28 per cent and insufficiency and pain in one shoulder and arm in 41 per cent

The material did not permit comparisons of the results with regard to different surgical methods It was concluded that the poor results could probably be ascribed in about equal degree to persistent torticollis paralysis of the neck muscles after division of ventral roots and paralysis of the trapezius after division of the accessory nerve

Different possibilities of improving the results were discussed

1) Treatment in several stages with stepwise denervation of the muscles involved

2) Deafferentation of the neck musculature alternately to extensive deefferentation as the first measure

3) Denervation of the sternomastoid muscle without interference with the trapezius innervation

GENERAL CONSIDERATIONS

The results of dividing nerves and roots in torticollis dystonica must be evaluated with respect both to the effect on the symptoms of torti

collis and to the sequelae which are a direct consequence of denervation. Persistent symptoms of torticollis may be due to insufficient denervation, to reinnervation and to spread of the dystonic activity to new muscle groups. An attempt was made to assess to what extent these factors might have been responsible for the poor results in the Serafimer series (see above). Decisive conclusions in this respect can however only be made on the basis of personal examination of the patients.

The following categories of undesired side effects can be distinguished:

1. *Symptoms of insufficiency of the neck muscles.* For some time after bilateral division of the 3 uppermost ventral roots it is difficult for the patient to hold his head upright, besides which the mobility may be limited and a feeling of tiredness and pain because of muscular tension occur. As a rule the patients learn how to balance the head and in favourable cases the symptoms of muscle weakness disappear. But sometimes weakness, stiffness and pain persist.

2. *Secondary changes of the spine*: fixed malposition and spondylosis may develop if denervation interferes with the muscle balance. Torticollis as such, however, may have the same effect.

3. *Paralysis of the trapezius* is often without any therapeutic effect in torticollis and must therefore be regarded as an undesirable complication.[1] According to *Patterson & Little* (1943) the contralateral trapezius is involved in about 8 per cent and the homolateral in about 18 per cent, while the corresponding figures for the sternomastoid muscle is 47 and 19 per cent respectively. On denervation of the contralateral sternomastoid it should therefore be preferable to preserve the innervation of the trapezius in most cases.

4. *Paralysis of the diaphragm* can occur after division of the 4th ventral root, but if this is only done on one side the risk of respiratory insufficiency appears to be small.

5. *Paralysis of the outer larynx muscles* and the muscles of the hyoid bone can cause postoperative dysphagia. This is favoured by difficulty

[1] *Nordén* (1946) pointed out that injury to the accessory nerve sometimes gives rise to considerable symptoms because of paralysis of the trapezius. In addition to the well known symptoms of paralysis which at least among manual labourers may cause a considerable loss of working capacity, pain in the shoulder and the arm was reported in 14 of 16 cases. *Nordén* believed this pain to be due to tension in the plexus brachialis because of a dropping shoulder. The significance of this complication appears to have escaped attention in the literature on torticollis.

in holding the chin forward because of paralysis of the extensors of the neck and the sternomastoid muscle

6 *Symptoms of anesthesia following division of dorsal roots*

On examining the patients in the present series it was attempted to assess to what extent the results of operations were influenced by the abovemenioned complications

PRESENT MATERIAL

In the Lund series the cases were selected according to the following criteria

1) History of more than half a year (except in a few very severe cases)

2) Conservative treatment had proved unsuccessful

3) At the first examination the patient was informed of the risks involved in the operation and of its mutilating nature Only those patients who after due information definitely requested operation were accepted usually not until after they had been observed for some time

4) Old patients with signs of cerebral arteriosclerosis were not accepted for operation

5) Neither were any patients accepted with marked dystonia or dyskinesia of other types one of the patients developed such symptoms later

None of the patients showed any neurological signs apart from the torticollis. One reported slight weakness of the right hand for a day or so before the onset of the torticollis and one had had transient facial paresis

As regards diseases of possible causal importance one patient had had a fracture of the base of the skull 1 year before the onset of the torticollis one had had severe pertussis 1 month before the onset and one had had meningo encephalitis in association with parotitis 3 years before the onset Two of the patients reported torticollis in other members of the family one had a brother and a son with moderate and severe torticollis respectively the other had a sister with this disease In addition 2 sisters with typical torticollis dystonica were operated upon but they are not included in the present material because they have not been followed up long enough

The main reason why the patients wanted to be operated upon was the unnatural position of the head It was moderate in 9 cases and severe in 12 In 4 the involuntary movements of the head were moderate and in 5 they were severe The mal position or movement of the head was predominantly rotation in one direction in 16 cases (to the right in 10 to the left in 6) Alternating turning of the head in both directions was observed in 2 cases The head was bent backwards (retrocollis) in 1 case and mainly tilted to one side in 2 cases

The patients ages when first admitted were 20–65 years (average 41 years) 11 of the patients were females and 10 were males The patients had had the disease for 4 months to 13 years (average 5 years) at the time of the first operation

The overall average duration of hospitalization of patients was 40 days and post operative convalescence 9 months

The interval between the operation and the review was on the average 6½ years (range 1 to 13 years) In 3 cases it was less than 2 years

METHODS

Operative methods The main principle was to denervate the sternomastoid muscle on one side first and if that failed to give relief intradural division of cervical roots was done in a second stage

In 18 cases the sternomastoid muscle was denervated in the following way After local anesthesia the incision was made along the anterior edge of the muscle The accessory nerve was exposed to the edge of the trapezius and all branches to the m sternomastoideus were extirpated in their entirety To prevent regeneration in 14 cases a 3 4 cm long cylinder of tantalum foil (0 0? mm thick) was placed around that part of the accessor nerve medial to and behind the sternomastoid muscle

In 18 cases intradural root section was done after laminectomy of the 3–4 upper most cervical vertebrae under general anesthesia with the patient in the prone position In 9 of these cases not only the 3 uppermost motor roots were divided but also the 4th motor root on that side to which the head was turned and in 3 cases the cephalad half of the 4th root bilaterally As a rule the first ventral root could be approached without extirpation of the occipital bone Division of dorsal roots and denervation of the sternomastoid muscle was done in 3 cases (C_2–C_4 in 2 cases C_1 C_4 in 1 case) Denervation of the sternomastoid was the only operation in 4 cases

In one case in which troublesome dystonia persisted despite root section and denervation of the sternomastoid muscle it was decided to try to divide the rami posteriores below C_4 on one side A search of the literature failed to reveal any description of the operative technique After preparatory studies on corpses the following procedure was used The skin was incised just behind the anterior edge of the trapezius and carefully dissected from the superficial fascia in order to avoid injury to the accessory nerve The accessory nerve was identified by electric stimulation and after an incision had been made in the fascia parallel to the nerve the latter could be prepared and held aside The transverse processes were approached between the splenius and levator scapulae the transversooccipitalis (= semispinalis capitis) was divided exposing the loose layer between this muscle and the semispinalis cervicis The posterior tubercles of the transverse processes were used as orientation points Medially and posterior to these tubercles 3 nerves were encountered and identified as probably being rami posteriores 4–6 They were divided and the proximal nerve endings were covered with small plastic cap which were fastened with silver clips

Questionnaires The patients were re-examined by questionnaires formulated to yield data on persistent or recurrent symptoms of dystonia and insufficiency of the denervated musculature The answers obtained were compared and supplemented by data from the annual reports of their condition which the patients send regularly to the department and with results of the objective findings obtained at the follow up examinations The symptoms of muscular insufficiency were then grouped according to whether they were due to division of cervical roots (disturbed mobility and pain in the neck and dysphagia) or symptoms due to paralysis of the trapezius (disturbed mobility and pain in one shoulder and arm) only symptoms that were not present before the operation were included

Objective re-examination included functional examination of the neck and shoulder musculature ?0 patients were examined according to a standardized scheme and by the same examiner and within a period of 1 year The strength of

the different groups of neck muscles was tested according to *Kendall & Kendall* (1949) The active and passive mobility of the neck was also examined The results were recorded according to a 4 grade scale

RESULTS

There was no operative mortality Neither were there any serious postoperative complications apart from those due to neck muscle paresis

Transient complications

Paresis of diaphragm The 4th ventral root was divided completely or partially in 9 cases Postoperative roentgen examination of the diaphragm in 5 cases showed paresis in 2 In no instance were the symptoms or signs of respiratory insufficiency severe permanent

Difficulty in balancing the head was common during the early postoperative period but the patients soon learned to hold the head upright

Dysphagia of a transient nature occurred in 4 cases during the postoperative period

Permanent complications

Permanent slight swallowing difficulties were noted in 5 cases and moderate to severe difficulties in 2 One of these patients has to hold the chin with the hand to be able to drink and to tilt the head to one side every time she swallows The other patient finds it difficult to swallow liquid food Both these patients have signs of slight paresis of the infrahyoid musculature and decreased lordosis of the neck with indrawn chin The latter complication was observed in 9 patients (only 2 of whom had no swallowing difficulties at all)

Paresis of the cervical muscles is a desired effect of the operation If very severe *i e* if the patient cannot balance the head it is an undesirable complication which did not occur in any of our cases Inability to raise the head against gravity was noted in no case on backward bending of the neck (which is the most important function in this connection) in 1 case on forward bending of the head and in 1 on sideward tilt Moderate weakness was noted in 4 cases in backward bending in 10 on forward bending and in 4 on tilting of the head to one side and 2 on tilting to both sides This degree of weakness was further noted in 7 cases on rotating the head (5 to both sides 2 to one side)

Atrophy in the posterior musculature of the neck was moderate in 6 cases (unilateral in 2) and severe in 1 (unilateral). Differences in atrophy between right and left were not related to the number of roots divided. The atrophy of the sternomastoid muscle after division of the accessory nerve corresponded to the paresis (see below). This also applies to the trapezius muscle. None of the patients found the atrophy disturbing from a cosmetic point of view.

Scoliosis occured postoperatively in 6 cases. It was severe in 2 and moderate in 4. Two of these patients had been examined roentgenographically before operation and in neither had examination revealed any abnormality of the cervical spine.

The mobility of the neck was normal or practically normal in all directions in 9 patients. In 5 mobility was assessed as slightly and in 6 moderately reduced, *i.e.* about half of normal mobility (3 of them could not turn the head in one direction and 2 could not bend it back at all). The passive mobility was practically equal to the active mobility.

Pain occurred after operation in 5 of the patients. The pain involved the neck or back of the head and as a rule it was strikingly correlated with the dystonic muscular activity, which was preserved in varying degree in this group.

Symptoms from the shoulder and arm after division of the accessory nerve (total in 2 and partial in 18) could be explained by weakness of the trapezius muscle, droop of the shoulder and decreased range of active abduction. The strength of the trapezius was moderately decreased after partial division of the accessory nerve in 8 cases and after total division in 1. All these cases had a slight to moderate droop of the shoulder. The range of active abduction against gravity was slightly limited in 2 patients after partial and in 1 after total division of the accessory nerve (160–170°, with the arm straight).

Shoulder pain occurred in 2 patients with moderate weakness of the trapezius after partial division of the accessory nerve. The pain was moderate. Two of the above mentioned 9 patients reported that the symptoms interfered with their working capacity. In one of these 2 the accessory nerve had been completely divided.

Loss of sensibility in the 3 patients who had undergone division of dorsal roots was moderate in 2 cases and corresponded to the denervated segment. The patients were not troubled by the hypesthesia. In the 3rd case no decrease in sensibility could be demonstrated (C_1–C_4 divided bilaterally).

Persistent dystonia

At the re examination 14 patients showed signs of persistent dys tonia 11 patients found this symptom embarrassing In 2 cases palpa tion and inspection revealed dystonic activity despite the absence of in voluntary movements of the head or other symptoms of torticollis

The malposition of the head was severe in 1 patient moderate in 4 and slight in 9 while in 7 the position of the head was normal Invo- luntary movements were severe in 1 patient moderate in 1 and slight in 5 while 13 were free from this symptom Tremor was severe in 2 slight in 8 and absent in the other 10 patients

Dystonic activity of the neck muscles was observed in 9 patients but produced no symptoms in 4 of them The remaining 5 4 of whom had undergone division of ventral roots had both symptoms and signs of dystonia which were slight in 4 and moderate in 1

At the re examination considerable dystonic activity of the sterno- mastoid muscle was observed in 9 patients but produced no symptoms in 4 of them Of the other 5 all of whom had undergone partial division of the accessory nerve 4 had moderate and 1 severe symptoms of dys tonia

In 6 of the 14 patients with persistent dystonia dystonic activity of the trapezius was noted after partial division of the accessory nerve In 3 of them the picture was dominated by dystonia of other muscles *while such activity of the trapezius appeared to cause moderate* or slight distress

Two of the 3 patients who had undergone division of dorsal roots had signs of slight persistent dystonia but all 3 reported symptoms of ten sion from the neck muscles which were generally hypertrophic

Recurrences

Six of the patients described in the preceding section had clear cut recurrences of torticollis after initial improvement

Reinnervation of the sternomastoid muscle was the main cause of recurrence in 2 cases 12 years before the re examination 1 of them had undergone partial division of the accessory nerve without insertion of a tantalum sheath He was troubled by severe dystonic activity of the muscle in question which was very strong and hypertrophic He never theless declined reoperation The other patient also had symptoms of torticollis due partly to dystonia of the sternomastoid although the

uscle was moderately weak after denervation with insertion of a tan
ilum sheath 7 years previously

Some function of the sternomastoid muscle was noted in 11 of the 16
ases where the muscle had been selectively denervated Of the 4 ope
ated upon without insertion of a tantalum sheath 2 had to be reope
ated upon 1 year and 7 years respectively after the operation the 3rd
f these patients had refused reoperation (see above) while in the 4th
e muscle was of normal strength 12 years after operation After de
ervation with insertion of a tantalum sheath the strength of the mus
le was normal in 1 patient moderate in 4 and greatly redused in 8

In 3 cases with recurrences the deterioration was due mainly to dys
nic activity having reappeared in the neck muscles All 3 patients
omplain of a troublesome pull of the neck muscles but they have full
orking capacity In 1 of these cases an unsuccessful attempt to se
ure relief by extradural division of the rami posteriores (see page 107)
as made This patient differs from the remainder in that the dystonia
ended to migrate from one muscle group to the other though without
nvolving more caudal segments

Propagation to caudal segments The patient in whom the poorest
esult was noted at the re examination had begun to show signs of
pread in caudal direction of the disease He complained of "pulling in
ll directions in one half of the body

Evaluation of the results

The patients opinions of the effect of the operation on the torticollis
s a whole (symptoms of muscular insufficiency included) were no
mprovement in 1 case moderate improvement in 5 cases considerable
mprovement in 14 cases and complete recovery in 2 cases As to work
ng capacity judged by the examiner the results were none in 1 case
severely impaired in 2 cases moderately impaired in 8 cases and normal
n 11 cases See also Tables 1 and 2

An attempt to treat the results numerically showed no significant
difference between the operative methods used the groups compared
being too small

Postoperative physical therapy

In most cases the patients received educational exercise and massage
after the operation while they were in hospital and several of the
patients also received physical therapy after discharge The treatment

TABLE 1

Patients estimate of the result

	No improvement	Moderate improvement	Considerable improvement	Complete recovery (symptomfree)
Serafimer Hospital	8 cases (= 16 %)	9 cases (= 18 %)	25 cases (= 50 %)	8 cases (= 16 %)
Lund	1 case	5 cases	14 cases	2 cases
Total (72 cases)	9 cases (= 13 %)	14 cases (= 19 %)	39 cases (= 54 %)	10 cases (= 14 %)

TABLE 2

Working capacity

	None	Severely impaired	Moderately impaired	Normal
Serafimer Hospital	3 cases (= 6 %)	9 cases (= 18 %)	23 cases (= 46 %)	15 cases (= 30 %)
Lund	1 case	2 cases	8 cases	11 cases
Total (72 cases)	4 cases (= 5 %)	11 cases (= 16 %)	31 cases (= 43 %)	26 cases (= 36 %)

and the results of this treatment were not studied systematically. The purpose of the treatment was to teach the patient to balance and keep the head upright as soon as possible and to prevent decrease in mobility due to contracture and malposition of the spine. Relaxation exercises in 2 cases were unsuccessful. In 2 other cases who complained in a late stage of neck stiffness physical therapy was followed by a marked subjective and objective improvement.

DISCUSSION

The results of operation will of course vary with the criteria used in the selection of patients for surgery. Differences in these criteria also make comparison between different series difficult. Occasionally torticollis dystonia is only part of a more extensive dyskinetic syndrome or a symptom of generalized cerebral arteriosclerosis. The acceptance of such cases for operation will of course reduce the overall results. On the other hand the acceptance of early cases observed for only a short time before operation and of mild cases might give a too favourable impression of what can be expected from operation.

TABLE 3

	No of c	Op mort lity	Unimpro d	Impro ed	Cured or s mptom fr e
nney & Hughson 19?5 Bilateral re ction of rami posteriores	31	0	3 (10 %)	16 (52 %)	1? (38 %)
ndy 1930 Bilateral resection of ven il and dorsal roots	8	1		2	5
llerson & Little 1943 n surgical treatment	197	0	12? (6? %)	7? (38 %)	
ction of accessory nerve	19	0	7	11	1
lateral section of cervical roots ith or without acc nerve section)	8	0	0	8	0
indberg 1946 (Olivecrona s series) ction of accessory nerve	11	0	3	7	1
lat ral section of cervical roots ith r without acc nerve section)	36	0	5 (13 %)	24 (67 %)	7 (20 %)
itnam et al 1949 Bilateral section entral roots with or without acces r nerve section	16	0	?	12	2
ppen & Martine Viochet 1951 Bi teral ection of dorsal and ventral ts (2? cases) section of acces ory r e (2? cases) excision f stern ast id (11 ca es)	37	1	14 (38)	22 (59 %)	0
ygis & Moore 1954 Mainl bilateral cti n of ventral r ots and section of ry ner e	9	0	0	1	8
K n i 1955 Bilateral section of ntral root access ory nerve section	12	0	0	10	2
rma & Troupp 1958 Bilateral sec n f ventral r ots intradural section c e ory nerve	18	?	3	10	3
nervati n of stern mast id	5	0	5	0	0
ndberg & Svantesson 1960 nervation f sternomastoi l	4	0	0	4	0
l teral section of cervical roots ith r without acc nerve section)	18	0	1	15	2

Tal le 3 summarizes the re ults given by the authors cited in our historical review The classificati n used here may tend to give a somewhat wrong impre sion of the riginal reports It was n t p ssible to include the report of *Adson et al* (1946 ee page 103) in Table 3

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DISCUSSION

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roots and dorsal roots respectively. However, observations discussed in the preceding paragraph argue definitely against resection of the entire accessory nerve as a first measure and suggest that one should always avoid denervation of the trapezius unless it is obvious that this muscle actively contributes to the dystonia. Such denervation should be preceded by transient blockage of the nerve by injection of alcohol or crushing of the nerve. Selective denervation of the sternomastoid muscle requires only a minor operation without risk of complications and may be chosen as the initial measure in suitable cases, particularly in those with only mild symptoms of dystonia. This operation may give the patient some relief during the expectancy before root section is decided. If a patient has had severe disabling dystonia for a considerable time there is no reason why the treatment should not be started by root section. Section of the accessory nerve may then turn out to be unnecessary.

Our interest in division of the dorsal roots was prompted mainly by the impression that many of the postoperative complications were due to muscular insufficiency after division of the ventral roots. This, however, does not seem to be the case. In addition, the distressing symptoms after dorsal root division in 3 cases were, if anything, more severe than what was usually found after division of ventral roots, and the effect on dystonia, as judged by objective examination, was not better. Judging from the present investigation there is no reason to prefer division of the dorsal roots in the surgical treatment of torticollis dystonica.

At present the following procedure appears to offer the best results and should be used as a standard method: on that side to which the head is rotated the 4 uppermost ventral roots are divided, and on the other side the 3 uppermost roots. If necessary, a sternomastoid muscle showing dystonic activity is subjected to selective denervation.

SUMMARY

Fifty cases of dystonic torticollis operated upon at the Serafimer Hospital in 1926–1944 were reexamined by questionnaires. 22 cases treated in the neurosurgical department in Lund during 1946–1957 were reexamined by questionnaires and 20 of them personally by one and the same examiner. The average observation period for the first series was 8 years (at least 1½ years) and for the second 6 years (at least 13 months). There was no operative mortality or serious postoperative complication.

No reliable data are available on the frequency of spontaneous remissions in torticollis dystonia or at what interval after the onset remissions might be expected Of 43 cases described by *Herz & Glaser* (1949) spontaneous improvement occurred in 6 patients 6-10 years after onset and in 3 the symptoms disappeared spontaneously 1.5-6.5 years after onset In 3 cases short remissions also occurred Those cases in which spontaneous remissions were observed had been followed up for at least 3 months and on the average for 6 5 years

In view of these figures and the somewhat mutilating nature of the operation it might be questioned whether the preoperative observation period of 6 months used in the present series was not too short

Sequelae impairing the results In the report on the Serafimer series it was suggested that the results were impaired by three main groups of symptoms (see page 104) which according to the questionnaire answers *seemed equally important as causes of reduced working capacity* In the Lund series where the patients reports could be checked at personal examinations by one and the same examiner reduction of working capacity was found to be due mainly to persistent dystonic activity while division of ventral roots appeared to have only a slight invalidating effect

In the Serafimer series paralysis of the trapezius was considered to cause distressing symptoms and to impair working capacity in about half of the cases In the Lund series there was no instance of reduced working capacity because of paralysis of the accessory nerve This appears to imply a considerable advance It is true that selective denervation of the sternomastoid muscle implies a greater risk of reinnervation with recurrence of dystonic activity in this muscle In 2 cases of the present series recurrence of considerable dystonic activity in the denervated sternomastoid muscle occurred Reoperation is however a minor procedure and was considered indicated in these cases Extirpation of the sternomastoid muscle as used *e g* by *Poppen & Martinez Niochet* (1951) might also be indicated in such cases

The erratic appearance of dysphagia which was prominent in only 2 out of 22 cases must be due to variations in the innervation of the swallowing muscles This complication can hardly be eliminated by modifying the method of operation but suitable exercise in an early stage may be of benefit

Choice of operative method The two series do not permit any statistical comparison regarding the results obtained by different combinations of the 3 procedures *i e* division of the accessory nerve ventral

Les deux series de cas comprennent au total 40 cas operes d'apres la methode standard suivante division du nerf accessoire (complète ou partielle) + division bilaterale des 3–4 racines ventrales superieures. Ces 40 malades decrivent comme suit les resultats obtenus

Pas d'amelioration	Amelioration moderee	Amelioration considerable	Disparition des symptomes
5 cas	8 cas	21 cas	5 cas
(12 5 %)	(20 %)	(52 8 %)	(15 %)

Les resultats pour les deux series (y compris les cas operes seulement par la division des nerfs accessoires et la division des racines dorsales) ont ete sensiblement les memes. Dans 9 cas traites par section bilaterale des racines dorsales (uniquement ou en combinaison avec la section des racines ventrales) les resultats n'ont pas confirme l'idee que cette operation etait préferable.

Dans la première serie la paralysie du muscle trapeze apres la division du nerf accessoire s'avère etre responsable d'une partie considerable (en gros ⅓) des maigres resultats. Dans la seconde serie le nerf accessoire n'a ete que partiellement divise l'innervation du trapeze avant ete conservee et la reinnervation du muscle sterno mastoidien avait ete empechee par une gaine d'un feuillet de tantale autour du nerf. La paresie du trapeze n'a ete dans aucun cas responsable d'une capacite de travail diminuee dans la seconde serie. La capacité de travail s'est trouvée reduite principalement par suite d'une dyskinesie ou d'une dystonie persistante. L'incapacite causee par une paresie due a la section de la racine était relativement insignifiante.

La division bilaterale des racines ventrales superieures si necessaire completee par denervation selective du muscle sterno mastoidien suivie d'une physiotherapie appropriee semble etre le meilleur traitement que l'on connaisse jusqu'ici pour les cas graves de torticolis.

ZUSAMMENFASSUNG

Funfzig Falle von dystonischem Torticollis die am Serafimer Krankenhaus in den Jahren 1926 1944 operiert worden waren wurden mittels Fragebogen nachuntersucht. 22 Falle die an der neurochirurgischen Abteilung in Lund von 1946–1957 behandelt worden waren wurden mittels Fragebogen und 20 Falle wurden personlich von ein und demselben Untersucher nachuntersucht. Die durchschnittliche Beobach

tungszeit für die erste Untersuchungsreihe war 8 Jahre (zumindest 16 Jahre) und für die zweite 6 Jahre (zumindest 13 Monate) Kein operativer Todesfall oder ernstliche postoperative Komplikation trat auf

Diese beiden Untersuchungsreihen umfassten insgesamt 40 Fälle die gemäss folgender Standardmethode operiert worden waren Durchtrennung des N accessorius (vollständig oder teilweise) + doppelseit. Durchtrennung der 3–4 obersten ventralen Wurzeln Diese 40 Patienten beschrieben das Ergebnis folgenderweise

Keine Besserung	Mässige Besserung	Bedeutende Besserung	Symptom frei
5 Fälle	8 Fälle	21 Fälle	5 Fälle
(12 5 %)	(20 %)	(52 8 %)	(15 %)

Die Ergebnisse in sämtlichen Fällen (einschliesslich der Fälle die nur mittels Durchtrennung des N accessorius und der dorsalen Wurzeln operiert wurden) waren ungefähr die gleichen Die Ergebnisse in 9 Fällen die mittels doppelseitiger Durchtrennung der dorsalen Wurzeln (allein oder in Kombination mit Durchtrennung ventraler Wurzeln) behandelt waren unterstützen nicht die Annahme dass diese Operation vorzuziehen sei

In der ersten Reihenfolge schien die Lähmung des M trapezius nach der Durchtrennung des N accessorius zum grossen Teil (ungefähr $^1/_3$) für die schlechten Ergebnisse verantwortlich zu sein In der zweiten Reihenfolge wurde der N accessorius nur teilweise durchtrennt indem die Innervation des M trapezius bewahrt wurde und die Reinnervation des M sternocleidomastoideus mittels einer Scheide von Tantalumfolie um den Nerven verhindert wurde Parese des M trapezius war in keinem Falle die Ursache herabgesetzter Arbeitsfähigkeit in der zweiten Reihenfolge Die Arbeitsfähigkeit war hauptsächlich wegen fortgesetzter dyskinetischer und dystonisher Aktivitet verringert indem die Störung die als eine Folge der Wurzeldurchtrennung auftrat relativ unbedeutend war

Doppelseitige Durchtrennung der oberen ventralen Wurzeln wenn notwendig kombiniert mit einer selektiven Denervation des M sternocleidomastoideus und einer adäquaten physikalischen Behandlung scheint zur Zeit die beste Behandlungsart für schweren Schiefhals zu sein

REFERENCES

Adson A W Young H H & Ghormley R K Spasmodic torticollis Severe organic type treated by combined operation rhizotomy and fusion Journ Bone & Joint Surg 28(2) 299–308 1946

Coleman C C Treatment of spasmodic torticollis by intradural posterior root section Virginia Med Monthly 53 761–765 1927

Dandy W F An operation for the treatment of spasmodic torticollis Arch Surg 20 1021–1032 1930

Finney J M T & Hughson W Spasmodic torticollis Ann Surg 81 255–269 1925

Foerster O Zur Analyse und Pathophysiologie der striaren Bewegungsstorungen Ztschr f d ges Neurol u Psych 73 1–169 1921

Foerster O Mobile spasm of the neck muscles and its pathological basis J Comp Neurol 58 725–735 1933

F ll E L Knopp L M & Ward A A Jr Experimental spasmodic torticollis J Neurosurg 16 55–67 1959

Frazier C H Spasmodic torticollis Interruption of the afferent system alone Ann Surg 91 848–854 1930

Her E & Glaser C H Spasmodic torticollis II Clinical evaluation Arch Neurol & Psychiat 61 227–239 1949

Her F & Hoefer P F A Spasmodic torticollis I Physiologic analysis of involuntary motor activity Arch Neurol & Psychiat 61 129–136 1949

Keen W W A new operation for spasmodic wryneck Ann Surg 13 44–47 1891

Kemberling S R Baird H W & Spiegel E A Experimental torticollis of rhombencephalic origin J Neuropath Exp Neurol 11 184–191 1952

Kendall H O & Kendall F P Muscles testing and function Baltimore 1949

Lundberg N G Surgical treatment of spasmodic torticollis 2nd annual meeting Scand Soc Neurol Surg Stockholm 1946

McKenzie K G Intrameningeal division of the spinal accessory and roots of the upper cervical nerves for the treatment of spasmodic torticollis Surg Gyn & Obst 39 5 10 1924

McKenzie K G The surgical treatment of spasmodic torticollis Clin Neurosurg 2 37–43 1955

Norlen K Peripheral injuries to the spinal accessory nerve Acta chir scand 95 515–532 1946

Olivecrona H Der spastische Schiefhals und seine chirurgische Behandlung Arch f klin Chir 167 293–301 1931

Patterson R M & Little S C Spasmodic torticollis J Nerv & Ment Dis 98 571–599 1943

Poppen J L & Martinez Niochet A Spasmodic torticollis Surg Clin N America 31 883–890 1951

Putnam T J Diseases characterized by involuntary movements In Surgical treatment of the nervous system" ed by Bancroft & Pilcher Lippincott Philadelphia 1946 page 299

Putnam T J Herz F & Glaser C H Spasmodic torticollis III Surgical treatment Arch Neurol & Psychiat 61 240–247 1949

Quervain de F Le traitement chirurgical du torticollis spasmodique d apres la méthode de Kocher Semaine médicale 16 405–409 1896

Taylor A S An operation for relief of spasmodic torticollis In Operative therapeusis by I Johnson ed by D Appleton & Co New York 1915 pp 533 5

Torma T & Troupp H Spasmodic torticollis Ann Chir & Gyn Fenn 47 401–419 1958

Wycis H T & Moore J R The surgical treatment of spasmodic torticollis J Bone & Joint Surg *36 A* 119–126 1954

FROM THE ORTHOPAEDIC CLINIC HÄRNÖSAND
(HEAD: NILS LINDSTRÖM)

OSTEOSYNTHESIS IN PSEUDARTHROSIS OF THE HUMERUS DIAPHYSIS

By

JAMES HINDMARSH and LARS UNANDER SCHARIN

The principles of treatment for pseudarthroses of the long bones are well known to have been much debated and the number of methods employed are very great. Diaphysis pseudarthroses of the humerus are considered by many to belong to the more difficult types to treat. Good treatment results have nevertheless been reported. The results presented by *D'Aubigne* and *Solal* (1950) belong to those more worthy of note. Using Küntscher nailing and tibia transplantation fixed by screws as an onlay graft, healing was obtained in 18 out of 19 cases = 94.7 %. Using fixation only with screwed on tibia transplants following resection of the pseudarthrosis the same authors obtained healing in 12 out of 13 cases = 92.4 %. Lange reported in 1953 an incidence of 87 % healed in a series comprising 126 humerus pseudarthroses. A detailed account of the operative methods used is not given, although in general intramedullary osteosynthesis is recommended with Kuntscher nail + tibia bone graft as an inlay or onlay graft fixed with cerclage or screws. *Maat* reported good results using the so called "Markraumfeder".

During the years 1946–1959 at the Orthopaedic Clinic Institute for Cripples, Härnösand, 18 cases of pseudarthroses of the humerus diaphysis and of diaphysis fractures of the humerus were operated on, the latter showing delayed healing. 15 cases have been considered as clear pseudarthroses. The period from initial injury to pseudarthrosis operation varied here between 10 months and 5 years, averaging about 22 months. In the three cases designated as delayed healing the period between initial injury and operation was about 4 mths. in all cases. This may seem indeed a short time within which to define the cases as delayed healing, but after 4 mths. the possibilities of healing were judged radiologically to be extremely small and this was con-

firmed by the findings at operation (There was interposition of soft tissue and complete instability after previously inserted osteosynthesis material was removed)

17 patients achieved healing (94 4 %), 4 of them however only after reoperation With one exception where the patient s primary injury was cared for at the Orthopaedic Clinic the patients consisted of remission cases *from various hospitals in Norrland (North Sweden)*

TABLE 1

Fixation method	Fracture type			
	Transverse	Double	Oblique	Comminuted
Intramedullary	9	1		1
Plate	1			1
Cerclage		1	1	3
Conservative	1			
Total	11	1	1	5

Table 1 reviews the type and treatment of the original injury Transverse fractures were dominant with 11 cases 9 of these had Kuntscher nailing 1 was fixed by means of a plate and 1 was treated conservatively A double fracture was fixed by nail + cerclage A short oblique *fracture was fixed with cerclage 5 may be termed comminuted* fractures 1 of these had nailing 1 was fixed with a plate and 3 with cerclage Thus open reduction with inner fixation was performed in 16 out of the 18 cases Only 2 of the fractures were open

A more detailed analysis of the reasons why the pseudarthrosis arose could not be made since we did not have access to the fracture material of the hospitals Probable contributory causes could however be traced in many cases In a number of cases it was a question of severe multiple injuries so that a suitable fracture treatment was much delayed In some cases the open reduction was to judge from the available X rays not successful In 2 cases which had Kuntscher nailing the bone cracked when the nail was struck home and a large intermediary fragment arose 1 case had a large intermediary fragment which was removed at operation Lack of fixation following operation was probably in the majority of cases a factor of significance The patient was postoperatively treated as if a completely stable inner fixation was present and this judging from the evidence available was not the case For

example out of those with medullary nailing only 2 were provided postoperatively with a thoracobrachial plaster. As a rule no more than an abduction splint was supplied, sometimes only an arm sling, although the nail did not fill the medullary cavity so that it could have prevented rotation.

3 patients underwent pseudarthrosis operation before treatment at the orthopaedic clinic with negative results. For 2 of them operation comprised freshening of the fracture ends and osteosynthesis with Küntscher nailing and bone chips packed in a canal sawn up to the medullary cavity. In the third case the osteosynthesis was performed with a tibia bone graft screwed above the fracture site following resection of the pseudarthrosis.

TABLE 2

Completed in connection with the injury + previous treatment

	Radialisparese	Ulnarisparese	Comb. radialis- and ulnarisp.
Injury	4 (1)		
Op. treat.	2 (1)	1 (1)	2 (2 ulnp.)
Total	6 (2)	1 (1)	2 (2)

Figures in brackets state lasting pareses

Table 2 shows the incidence of nerve injuries connected with the accident and the previous treatment. The figures in brackets state permanent pareses. These were present therefore in 5 cases. 1 patient had almost total lasting pareses of the ulnar nerve, in other cases it was a question of slight pareses without any invalidising effect.

Our operative material is distributed between 14 men and 4 women, 8 right sided and 10 left sided cases. The average age at operation was 47.7 years, with the highest age 78 and the lowest age 20 years.

TABLE 3

Op. method		No. of cases
I	Freshening of fracture ends + osteosynthesis with Egger's plate + bone chips in a chiselled canal. Figs. 1a, 1b	14
II	Freshening of fracture ends + osteosynthesis with free bone transplant (tibia bone graft). Figs. 2a, 2b	2
III	Freshening of fracture ends + osteosynthesis with Küntscher nailing + free bone transplantation (tibia graft as onlay graft fixed with cerclage). Figs. 3a, 3b, 3c	2



Figs 1 a and b



Figs 2 a and b



Figs 3 a b and c

The operative methods used are shown in table 3 In the operative technique of method I quite long plates were employed as a rule and at least three screws were inserted on both sides of the pseudarthrosis The screws were always inserted through both cortical layers The canal was usually fully 1 cm wide and extended 3 to 4 cms along

each fragment It entered the medullary cavity Chips were taken from the ilium and consisted mainly of cancellous bone In method II one end of the tibia bone graft was pushed into the medullary cavity of the proximal fragment and the other end was sunk in a chiselled canal of the distal fragment All 3 methods always included exstirpation of fibrous tissue and freshening of the fracture ends Sclerotic bone was resected so that bleeding bone was present on both sides In some cases reoperated on this involved a not insignificant shortening In cases of delayed healing which were all operated on according to method I only slight freshening of the fracture ends was carried out however

Outer fixation with thoracobrachial plaster was retained in principle until radiological consolidation arose The fixation period varied between 2 and 10 mths and was on average 4 mths

TABLE 4

Method	No primary op	Primary healed	Reop	Completely healed	No of op
I	14	11	2	13	16
II	2	0	0	0	2
III	2	2	1	3	3
IV	0	0	1	1	1
Total	18	13	4	17	22

Table 4 gives the results with the respective methods With method I 14 patients were operated on 11 of which healed primarily Of the remaining 3 2 were reoperated on according to the same method with good results The third would not undergo any further operation and so represents the sole definitive non union in the series In all 13 out of 14 healed with this method after 16 operations Method II gave depressing results with no primary union Both patients were however reoperated on using other methods and then healed One was operated on according to method III and therefore with this method we had 3 healed out of 3 operations since the two operated on primarily also healed The other patient in method II was operated on by a method designated IV in the table the pseudarthrosis was resected during transformation into an oblique fracture and was fixed with screws

Of the 18 patients therefore 13 healed primarily Since the 4 reoperated also healed this makes a total of 17 healed

Throughout the operative series comprising 22 pseudarthrosis operations no complications were recorded in the form of nerve or blood

vessel injuries or of more severe infection although there was one case of slight wound infection It should be emphasised that aseptic pseudarthroses are involved In no case were signs of infection present at operation

16 patients were followed up 1 is dead and only some general information could be obtained from relatives concerning his working capacity following the operation 1 patient was able to leave relatively detailed information about his condition by letter The observation period in no case fell below 8 mths and at its longest was 13 years

Regarding the follow up only a few observations will be made here which may perhaps be of some interest We only saw a high degree of reduced strength in the arm in 3 patients who had all undergone repeated pseudarthrosis operations 6 patients had significant limitation of mobility in the shoulder and elbow joint while 5 of these also had considerable limitation of movement at the time of the pseudarthrosis operation In such a small series as this coincidence may of course be present but the circumstance still gives us cause to emphasise the importance of a patiently executed pre operative course of treatment in mobility which we believe is fundamental For it appears as if the patient in spite of the lengthy fixation as a rule obtains approx the same mobility as existed on the occasion of operation In some cases we believe we would have obtained a better end result if the patients had been afforded a longer period of exercise before the pseudarthrosis operation Shortening varied between 7 cms and an amount too small to be measured with accuracy We saw no reaction around the osteosynthesis material and this was never removed after healing

TABLE 5

	Returned to work	Changed work	Incapable of work
Manual work	7	3	2
No manual work	3	0	0
Household work	2	0	0
Total	12	3	2

Table 5 gives a rough estimation of work capacity Of the 12 manual labourers 7 returned to the same work and 3 were changed to lighter work 2 were not capable of work the one owing to chronic uremia from which disease he afterwards died the other probably mainly owing to psychological reasons since objectively the arm was fairly

satisfactory Of the 3 who were white collar workers 2 declared them selves capable in their leisure time of carrying out heavier manual work Both housewives said that they could see to all household chores One patient aged 81 at the time of the follow up and who hardly had any work was not included in the table

DISCUSSION

As far as the principles defining pseudarthrosis are concerned we followed those laid down by *Bertelsen Birn Christiansen* and others in the Danish Medical Bulletin 1955 these are that a case may be de signated pseudarthrosis within 12 mths if 1) a defect exists 2) plain sclerosis of the fracture ends and closure of the medullary cavity are found or if 3) it can be confirmed at operation that muscle or tendon tissue are interposed

Regarding the type of pseudarthrosis the three cases previously sub mitted to pseudarthrosis operations and in whom resection had been performed can be designated as defect pseudarthroses On reoperation of the four cases where we did not achieve primary union defects were also present in that the previously inserted osteosynthesis material was removed Thus there were 7 operations on defect pseudarthroses (in 5 of these operations method I was used in one method III and in one method IV) In the other operations no bone defect was present This does not however mean that it was always a question of contact pseudarthroses This phrase refers chiefly to a pseudarthrosis in which the fracture ends are held together by a fibrous callus tissue in fairly good contact Amongst our cases however there are also dis located loose pseudarthroses which therefore can neither be designated as contact or defect pseudarthroses

Method I includes by far the majority of cases (14 cases 16 opera tions) and therefore deserves further discussion The results may here be considered as satisfactory with regard to the total number of healed cases (13 out of 14) but the fixation period of 4 mths on average must be regarded as relatively long and from this point of view the method seems to be inferior to e g that by D Aubigne and Solal with nailing + tibia bone graft where only 1 mth of outer fixation is necessary ac cording to the information given

In spite of the good results reported by Phemister in various pseud arthroses of the long bones the majority of authorities seem to agree that a stable inner fixation is of essential importance in the healing of

vessel injuries or of more severe infection although there was one case of slight wound infection It should be emphasised that aseptic pseudarthroses are involved In no case were signs of infection present at operation

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3 In the treatment of diaphysis pseudarthroses of the humerus the above mentioned method I may be described as an acceptable alternative to D Aubigne s or Palmer s methods without being recommended as superior to these

4 Patients with joint contractures ought to have time to exercise before the pseudarthrosis operation is undertaken

SUMMARY

A series is reported consisting of 15 pseudarthroses and 3 fractures with delayed healing located to the humerus diaphysis these were operated on between 1946 and 1959 at the Orthopaedic Clinic Institute for Cripples Härnösand

In 14 cases the osteosynthesis was performed with Egger s plate and bone chips inserted into a canal chiselled up to the medullary cavity (method I) In 2 cases the osteosynthesis was performed with a tibia graft (method II) In 2 cases the osteosynthesis was performed by means of medullary nailing and a tibia graft as an onlay graft which was fixed above the pseudarthrosis with cerclage (method III) In all cases the bone had been resected so that fresh surfaces could be adjusted to each other

17 of the 18 cases healed 4 however only after reoperation

In the group operated on according to method I (14 cases) 13 healed (2 reoperations)

No complications in the form of nerve injury or more severe infection arose

The fixation period in the thoracobrachial plaster was 4 mths on average

16 patients were followed up and in the majority it was possible to confirm satisfactory function and work capacity 6 patients had limited mobility to a considerable degree in the shoulder and elbow joints although this was already present in 5 of these at the time of the pseudarthrosis operation This emphasises the importance of a patiently executed preoperative movement therapy

Method I is discussed and is considered as an acceptable method alongside the intramedullary osteosynthesis procedure

RESUME

Il est rapporte une serie de cas comprenant 15 pseudarthroses et 3 fractures localisees a la diaphyse de l humerus dont la guerison ne

s'était pas faite Ceux ci furent opérés entre 1946 et 1959 à la Clinique Orthopédique de l Institut des Infirmes d Härnösand

Dans 14 cas l ostéosynthèse a été réalisée avec la plaque Egger et des fragments osseux insérés dans un canal taillé jusqu à la cavité médullaire (méthode I) Dans 2 cas l ostéosynthèse a été réalisée avec une greffe de tibia (méthode II) Dans 2 cas l ostéosynthèse a été réalisée au moyen d un enclouage médullaire et d une greffe de tibia simplement *posée et fixée autour de la pseudarthrose par cerclage (méthode III)* Dans tous les cas on a pratiqué une résection de l os de manière à ce que des surfaces fraiches puissent être ajustées l une à l autre

Sur ces 18 cas 17 ont été guéris pour 4 toutefois seulement après réopération

Dans le groupe des malades opérés selon la méthode I (14 cas) 13 furent guéris (2 réopérés)

Il n y a pas eu de complications sous forme de lésion des nerfs ou d infection grave

La période de fixation dans un plâtre thoracobrachial a été en moyenne de 4 mois

16 malades ont été réexaminés et dans la majorité des cas on a trouvé la confirmation d une fonction et d une capacité de travail satisfaisantes Chez 6 malades la mobilité était réduite à un degré considérable dans les articulations de l épaule et du coude mais pour 5 c était déjà le cas au moment de l opération de la pseudarthrose Cela souligne l importance de la thérapie pré opératoire du mouvement chez les malades

La méthode I est discutée et est considérée comme une méthode acceptable à côté du procédé de l ostéosynthèse intramédullaire

ZUSAMMENFASSUNG

Über eine Reihe von 15 Pseudarthrosen und 3 Brüchen der Humerusdiaphyse mit verspäteter Heilung wird berichtet Diese Fälle wurden zwischen 1946 bis 1959 an der orthopädischen Klinik des Institutes für Krüppel in Härnösand operiert In 14 Fällen wurde die Osteosynthese mit der Egger Platte und Knochenspähnen die in einen bis zur Markhöhle aufgemeisselten Kanal eingelegt wurden ausgeführt (Methode I) In 2 Fällen wurde die Osteosynthese mittels einer Tibiaspange vorgenommen (Methode II) In 2 weiteren Fällen wurde die Osteosynthese mittels Marknagelung und einer angelegten Tibiaspange die oberhalb der Pseudarthrose mittels Cerclage fixiert wurde (Methode III) aus

geführt In allen Fallen wurde Knochen reseziert so dass angefrischte Oberflächen aneinander gelegt werden konnten

17 von den 18 Fällen heilten 4 jedoch erst nach Reoperation In der Gruppe die nach Methode I operiert wurden (14 Falle) heilten 13 (2 Reoperationen)

Keinerlei Komplikationen wie Nervenbeschädigung oder schwerere Infektionen traten auf

Die Dauer der Ruhigstellung im Thorax Armgips betrug im Durchschnitt 4 Monate

16 Patienten wurden nachuntersucht und bei der Mehrzahl konnte eine Zufriedenstellende Funktion und Arbeitsfähigkeit festgestellt werden 6 Patienten hatten eine bedeutende Einschränkung der Beweglichkeit im Schulter und Ellbogengelenk doch war dieselbe bei 5 bereits zur Zeit der Pseudarthrosenoperation vorhanden Dies zeigt die Wichtigkeit einer geduldig ausgefuhrten Bewegungsbehandlung vor der Operation an

Methode I wird besprochen und wird zusammen mit der intramedullaren Nagelung als eine brauchbare Methode angesehen

REFERENCES

1 *Bertelsen A* and others Treatment of pseudarthrosis of l ng bones in Denmark Danish Medical Bulletin 2 1–7 1955

2 *D Aubigne R M & Solal* Le traitement des pseudarthroses de la diaphyse humérale Revue d orthopedie 36 373 1950

3 *Fehr A M* Die Behandlung der Pseudarthr se und ihre Ergebnisse (Diskussion M Lange) Helvetia chirurgica acta 20 355 1953

4 *Fehr A M & Rieben W* Weitere Erfahrungen mit der Phemisterplastik Helvetia chirurgica acta 21 411 1954

5 *Jarry L & Uhthoff H K* Activation of osteogenesis b the "petal" technique Journal of Bone and Joint Surgery 42 B 126–36 1960

6 *Küntscher G* Funfzehn Jahre Marknagel Langenbecks Archiv 282 211 1955

7 *Küntscher G* Der Wirkungsmechanismus des Phemister Spanes Der Chirurg 26 23 28 1955

8 *Küntscher G* Pseudarthr e nach Marknagelung Zeitschrift fur Orthopedie (Stuttgart) 87 295 1956

9 *Palmer I* A dualistic method of treating pseudarthrosis Acta chir scand 107 261 19 4

10 *St ren G* The incidence f pseudarthrosis with different methods of treatment in a fairly large fracture series Acta rthopaedica scand 25 69–76 1955

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"KISSING SPINE" SYNDROME IN THE LIGHT OF AUTOPSY FINDINGS

By

PENTTI M RISSANEN

The first worker to report roentgenologico clinically on the syndrome which is often called Baastrup s disease was *Baastrup* (1933 a 1933 b) after whom it was named He noted that the tips of the spinous processes are pressed against one another when lordosis of the lumbar spine is intensified for one reason or another and in consequence of the resulting trauma hemorrhages develop initially in the interspinous tissue Later the soft interspinous tissues are destroyed the tips of the adjacent spinous processes move very close together and formations which are roentgenologically reminiscent of joints may develop The tips of the spinous processes as it were kiss one another which has given rise to the name kissing spine syndrome used by some workers and first introduced by *Brailsford*

The kissing spine syndrome has subsequently been studied by numerous workers from the roentgenological clinical and therapeutical aspects (*Reinhardt* 1951 *Toison et al* 1957 etc) *Saltini* (1954) regarded the syndrome as congenital rejecting the mechanical theory put forward by *Baastrup* He stated that he had even established some degree of heredity *Vilaseca et al* (1953) reported that the disease occurs chiefly in women (77 per cent) during or after the menopause It was reported by *Bachmann* (1956) that these changes in the spinous processes are more common than is believed he established Baastrup s disease in 27 per cent of the roentgenograms of 70 patients A method of treatment was introduced by *Franck* (1944) in which a part of the spinous processes is resected in the most severe kissing spine cases The present author has found nothing in the literature however on the macro- and microanatomical changes encountered in the spinous pro-

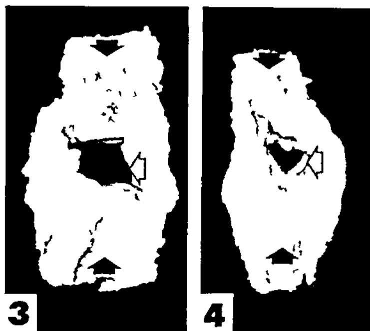
cesses and the soft parts between them the interspinous ligaments in cases of kissing spine

Own investigations Using an autopsy material the spinous processes in the region of the lumbar spine and their interspinous ligaments were studied in a total of 306 dead bodies Of them 114 were children under 10 and the remainder 192 represented fairly evenly all age groups up to 90 No changes indicative of Baastrup s disease were observed grossly or microscopically in the spinous processes and interspinous ligaments of the child material The margins of the spinous processes were sharp in children there were no faceted or articular surfaces and no osteophytes This suggests that the "kissing spine syndrome cannot be a congenital disease but must develop later in life

Incipient degenerative changes which are gradually intensified with age can be established histologically and histochemically in the lowest interspinous ligaments of the lumbar spine by around the age of 20 In consequence of these changes small cavities originate in the middle of the interspinous ligaments and the actual tendinous tissue is gradually destroyed until only a thin layer of ligament tissue remains on both margins of the ligament At the same time the corresponding interspinous ligaments thicken ostensibly measured from outside from 1–2 mm in young persons to as much as 10 mm and more in thickness later







Figs 1–4

Frontal plane sections of spinous processes and their interspinous ligaments in cases of "kissing spine" of different degrees of severity. Short black arrows in the upper and lower margins of the illustrations indicate cross sections of the bony surfaces of the spinous processes. White arrows indicate small cavities reminiscent of joint cavities between the spinous processes and inside the interspinous ligaments. Black curved arrows indicate osteophytes at the margins of the spinous processes.

in life. With the thickening of the interspinous ligaments the corresponding margins of the spinous processes also thicken. The formation of cavities in the middle of the interspinous ligaments is so common that a cavity was demonstrated macroscopically in the ligaments of the LIV–LV space in 85 per cent of subjects of, say, 61–70 years of a[ge] (*Rissanen* 1960).

It is possible to find in typical cases of "kissing spine" from an external examination of the spinous processes and their interspinous ligaments that the ligaments are always markedly thickened. Osteophytes often seem to form on the margins of facing spinous processes on the lateral sides. These osteophytes constitute a typical aspect of this disease (Fig. 1). The tips of the spinous processes either project until they are together or separated by a narrow slit only. Outwardly the interspinous ligaments may consequently appear perfectly intact, merely noticeably thick.

The macroanatomical changes that have developed in the spinous processes and interspinous ligaments in Baastrup's disease can be seen more distinctly in a frontal plane section running via the spinous processes and the interspinous ligament between them (Figs 1–4). It can often be seen how the margins of the facing spinous processes have shaped themselves into oblique faceted surfaces (Figs 1–2) which slide against one another easily when the tips of the spinous processes are pressed together. The pearly grey colour characteristic of the articular surfaces is often visible on the faceted surfaces. There is generally a large cavity in the middle of the interspinous ligaments and sometimes thin membranes on both margins are all that remain of the true ligament. The ligament tissue may also be destroyed completely in places.

It is easy to discriminate macroanatomically between pronounced and typical "kissing spine" cases. *But it is difficult to draw a line between cases in which the changes are mild and normal spinous processes* since there are numerous transitional forms between normal and the "kissing spine" condition. Approximation of the tips of the spinous processes to one another occurs with increasing age in most cases and most extensively in the lowest lumbar vertebrae. There is concomitant cavity formation in the middle of the interspinous ligaments and the margins of the spinous processes are thickened. As already mentioned a major or minor cavity was found on macroscopical examination in the middle of the interspinous ligament of the LIV–LV space in 85 per cent of subjects aged 61–70. The larger the cavity the closer together were the tips of the spinous processes as a rule and consequently the greater their resemblance to "kissing spine".

Tissue resembling hyaline cartilage can be demonstrated microscopically in typical cases of Baastrup's disease in the spinous process margins that have turned to face one another (Fig 5). This tissue shows cartilaginous cell capsules in the middle of metachromatically staining ground substance.

Metaplastic cartilage originates in "kissing spine" next to the bony surface of the spinous process. All the cases examined by the present author however involved at least in places tissue resembling markedly degenerated hyaline cartilage in which the majority of the cells were necrotised. *On the other hand large colonies of cartilage cells were* visible in parts; they sometimes consisted of even tens of cells, some and in places even all of them necrotic. Toluidine blue and Alcian blue staining sometimes revealed the disappearance of metachromasia or

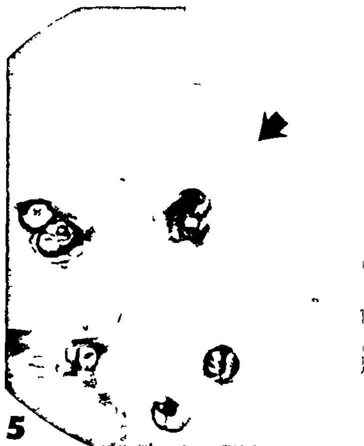


Fig 5

Edge of a cavity (arrow) seen from the side of the spinous process in a typical case of Baastrup's disease Metaplastic tissue resembling hyaline cartilage tissue no longer any metachromatic staining in the marginal parts Toluidine blue × 400

its weakening in the marginal parts although it was still intense in the inner parts

A mesothelial covering which circumscribed the cavities was often demonstrable microscopically on both lateral sides of the interspinous ligaments (Fig 6) Folds villi which could be lined by a layer of cells pushed from here into the cavity in places The kissing spine cases consequently showed a cavity in the middle of the interspinous ligaments sometimes bounded towards the spinous processes by tissue resembling joint cartilage and in the lateral direction often by a formation reminiscent of the articular capsule and containing a synovial membrane Macro and microanatomically demonstrable joints thus



Fig 6

Edge of a cavity (arrow) seen from the lateral aspect in a typical case of Baastrup's disease Loose connective tissue bounded towards the cavity by a layer of mesothelial cells Toluidine blue × 400

formed between the tips of the spinous processes in the "kissing spine" cases

DISCUSSION

Judging by the material studied Baastrup's disease is certainly not a congenital disease but develops gradually during life when the tips of the spinous processes move together for some reason or other Although cases of pronounced "kissing spine" were relatively rare in the adult material milder cases were numerous from roentgenograms

Bachmann (1956) reported changes indicative of Baastrup's disease in 27 per cent of his cases Changes suggestive of this disease are still more readily demonstrable at autopsy the number of cases increasing with the age of the material Changes suggestive of Baastrup's disease are very common after middle age Changes of this type very probably have a prominent role in the production of low back pain when the involvement is still mild

SUMMARY

The spinous processes of the lumbar spine and the soft parts between were studied in 306 dead bodies for the presence of Baastrup's disease 114 were children under 10 and the remainder were evenly distributed by age up to 90 No "kissing spine" was seen among the children The disease must consequently develop during life The macroscopical findings in typical "kissing spine" cases are thickening of the spinous processes oblique facets which often develop at the points of contact of the tips and small cavities resembling joint cavities which form in the middle of the interspinous ligaments Microscopical study discloses tissue components typical of joints and thus true neoarticuli form in these cases between the tips of the spinous processes

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RESUME

Les apophyses epineuses de la colonne vertebrale lombaire et des parties molles intermediaires ont ete etudiees sur 306 cadavres pour *rechercher la presence de la maladie de Baastrup* 114 etaient des enfants de moins de 10 ans les autres etaient repartis dans toutes les categories d'ages jusqu'a 90 ans On n'a pas constate d'alterations chez les enfants C'est donc que la maladie se developpe dans le courant de la vie Les trouvailles macroscopiques furent dans les cas de "kissing spine" un epaississement des apophyses epineuses le developpement de facettes obliques sur les points de contact entre les apophyses et la formation de petites cavites ressemblant aux cavites articulaires dans les ligaments interosseux Une etude microscopique a revélé dans ce tissu les composants typiques des articulations et par consequent dans ces cas une veritable forme neoarticulaire entre les apophyses epineuses

ZUSAMMENFASSUNG

Die processus spinosi und die Weichteile zwischen ihnen wurden unter Hinblick auf das Vorhandensein von Baastrups Erkrankung bei 306 Leichen untersucht 114 waren Kinder unter 10 Jahren und die übrigen zeigten eine gleichmässige Altersverteilung bis zu 90 Jahren Keinerlei Berührung der Dornfortsätze wurde bei Kindern angetroffen Die Erkrankung muss sich daher während des Lebens entwickeln Die makroskopischen Befunde bei typischer Berührung der Dornfortsätze Kissing Spine sind Verdickung der Dornfortsätze schräge Facetten die sich oft an den Berührungspunkten der Spitzen entwickeln und kleine Hohlräume die Gelenkshöhlen ähnlich sind und die sich oft in der Mitte der ligg interspinalia bilden Mikroskopische Untersuchungen enthüllen Gewebskomponenten wie sie für Gelenke typisch sind und es bilden sich daher in diesen Fällen echte Neoarthrosen zwischen den Spitzen der Dornfortsätze aus

REFERENCES

Baastrup Chr Proc spin vert lumb und einige zwischen diesen liegende Gelenkbildungen mit pathologischen Prozessen in dieser Region Fortschr auf dem Geb der Röntgenstr 48 430 1933 a

Baastrup Chr On the Spinous Processis of the Lumbar Vertebrae and the soft Tissues between them and on pathological Changes in that Region Acta Radiologica *14* 52 1933 b

Bachmann R Über die Osteoarthrotischen Formveränderungen an den Dornfortsätzen der Lendenwirbelsäule Arch Orthop Unfall Chir 48 ? 171 19?6

Franck S Surgical Treatment of interspinal Osteoarthrosis (kissing spine) Acta Orthop Scandinav *15* 1?7 1944

H ppe D Beitrag zur Baastrupschen Krankheit Zentralblatt für Chir 8? 36 19?7

Reinhardt K Beitrag zur Baastrupschen Krankheit Deutsche med Wschr *12* 363 19 1

Rissanen P The Surgical Anatomy and Pathology of the Supraspinous and Interspinous Ligament of the Lumbar Spine with Special Reference to Ligament Rupture Acta Orthop Scandin Suppl 46 1960

Sal ini I Sulla cosidetta malattia di Baastrup Radi l Med *40/7* 6?3 19?4

T ison J Batique L Carlier C & T ison C La Maladie de Baastrup Journal de Radi l D Electr 38 1 1957

Vil ecr J M Barcelo P & Casadem nt M Nearthrosis interspin sa (enfermedad de Baastrup) Rev E p Reum 5 3 101 19?3

FROM THE ORTHOPAEDIC HOSPITAL OF THE INVALID FOUNDATION HELSINGFORS, FINLAND (HEAD: A. LANGENSKIÖLD, M.D.)

TRANSPOSITION OF THE TRACTUS ILIO-TIBIALIS TO THE PATELLA

As a Treatment of Quadriceps Paralysis and Certain Deformities of the Lower Extremity After Poliomyelitis

By

ERIK B. RISKA

The purpose of this paper is to present the results obtained in the Orthopaedic Hospital of the Invalid Foundation, Helsingfors, during 1943–1959 in the treatment of paralysis of the quadriceps muscle and certain deformities of the lower extremity after poliomyelitis. The treatment is reviewed on the basis of 63 cases in which transposition of the tractus ilio-tibialis to the patella has been performed. The conclusions drawn from these results have pointed the way to our present form of treatment (*cf. Hagelstam* in (7)).

In 1925 *Spitzy* suggested transposition of the iliotibial tract to the patella as a treatment for quadriceps paralysis following poliomyelitis (12, 13). His proposal was based on the fact that the tractus with the tensor fasciae muscle extends over two joints, being situated anteriorly of the axis of movement of the hip and posterolaterally of the axis of the knee joint. When the hip joint is extended, the tractus with its tensor muscle thus stretches and stabilizes the knee. He also pointed out, as did *Erlacher* (5), that the tensor fasciae latae muscle often escapes paralysis even when the flexors of the thigh are affected. In 1933 *Ober* pointed out the risk of recurvatum following transposition of the hamstring muscles and suggested that the tensor fasciae latae and sartorius be employed instead (10). In 1926 *Yount* gave indications for transposition of the tractus ilio-tibialis (15) and in 1938 presented his series of 16 cases in which good results had been obtained (16). In

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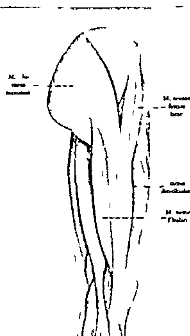


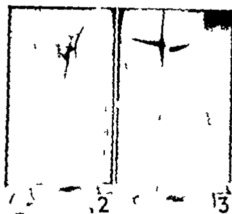
Fig 1

The tractus ilio tibialis sets out from the muscular fibres of the tensor fasciae latae muscle and the gluteus maximus being attached distally at the lateral condyle of the tibia

one half of these the biceps femoris had been used in combination with the tractus Apart from reports on isolated cases (1 14) no other series with transposition of the tractus ilio tibialis as the sole treatment of quadriceps paralysis has been published In 1940 *Debrunner* suggested that the tractus and sartorius should be used simultaneously for transposition in quadriceps paralysis stating moreover that it is not important to achieve a marked increase of the extension power of the knee joint since the patient does not necessarily require it when moving (4) He pointed out that the muscular power needed for transfer of the stabilizing power of the knee joint to the ligaments is small

ANATOMICAL CONSIDERATIONS

The tractus ilio-tibialis is composed partly of longitudinal and partly of transverse bands It sets out from the muscle fibers of the musculus tensor fasciae latae and gluteus maximus being inserted distally at the lateral condyle of the tibia (Fig 1) Part of the tractus reaches the



Figs 2 and 3

Case 24 — *Typical deformity* of the right lower extremity due to contracture of the tractus ilio tibialis in the late stage of poliomyelitis 3 years after onset of the illness Note the genu valgum external rotation of the tibia and flexion contracture of the hip

tibial tuberosity distally of the patella and isolated strands extend to the fibula One of its functions in a sound leg is to contribute to the locking of the knee joint in the last stage of extension by external rotation of the tibia

Because of its site and construction contracture of the tractus ilio-tibialis is probably one of the most important factors responsible for deformities of the lower extremities after poliomyelitis (Figs 2 and 3) Therefore *Irwing* (1949 9) and *Hodgkinson* (1957 8) recommend Yount s fasciotomy for the treatment of these deformities In this operation the functional muscle is not utilized whereas by transposition of the tractus to the patella both correction of the deformity and improvement of the function of the knee joint may be achieved

MATERIAL

The present series is made up of 63 cases 37 male and 26 female

As to the age at onset of the illness the largest group (26 cases) is made up of the youngest patients with ages ranging from six months to 3 years The explanation for this may be that the pareses are milder among the youngest patients

The interval between paralysis and surgery was less than 5 years in about half of the cases During this period a deformity had already developed in the paretic extremity owing to contracture of the tractus

ilio tibialis and the musculus tensor fasciae latae. Surgical measures were not carried out until two years after the patient contracted the disease and during this time there was both spontaneous improvement of the muscular function and an increase of muscular power achieved by means of physiotherapy.

The patients ranged in age from 3 to 49 years at the time of operation. 35 patients were under 15 and 28 were over 15.

TABLE 1

Transposition of the tractus ilio tibialis to the patella. Follow up cases from 1943–1959 in the Orthopaedic Hospital of the Invalid Foundation

	No. of cases
Male	37
Female	26
Total	63
Unilateral	59
Bilateral	2

TABLE 2

Distribution by age at acute stage of poliomyelitis

Years	No. of
$\frac{1}{2}$– 3	26
4–5	9
6–7	[illegible]
8– 9	4
10–11	3
12–13	3
14–15	4
16–17	3
18–19	1
20–21	2
[illegible]	1
29	2
33	1
40	1
47	1
Total	63

TABLE 3
Time elapsed from paralysis to surgery

Years	No of cases
2– 3	24
4– 5	11
6– 7	7
8– 9	7
10–11	4
12–13	2
14–15	2
20–21	2
25	1
32	1
41	2
Total	63

TABLE 4
Time from operation to last follow up examination

Years	No of cas
6/12–11/12	14
1– 2	12
3– 4	2
5– 6	3
7– 8	3
9–10	4
11–12	19
13	6
Total	63
Mean duration of follow up period	6 8 years

The average follow up period was about 7 years it was 11 to 12 years in the largest group (19 cases) of patients subjected to follow up examination At the end of the follow up period 39 patients were over 15 years old and thus their growth was practically complete while 24 patients were under 15 years of age

INDICATIONS FOR SURGERY

Indications for operation were in 28 cases paralysis of the quadriceps muscle with consequent limping and loss of stability of the knee joint

causing knee buckling and falling or hand to knee walking without fixed deformities In 27 cases fixed deformities of the lower extremities following contracture of the tractus ilio tibialis with its allied structures (genu valgum knee flexion deformity and external rotation of the tibia flexion and abduction contractures of the hip) were recorded as indications together with other factors In 19 cases it was thought that operation might enable the patient to discard his braces and/or crutches or that long braces comprising the entire leg could be exchanged for smaller ones for the ankle and foot

TABLE 5
Indications for operation

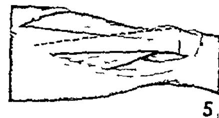
	Indication	No of cases
A	Quadriceps paralysis with limp and loss of stability	28
B	Fixed deformities	2
C	Brace and/or crutches	3
	A + B	14
	A + C	5
	A + B + C	9
	B + C	2
	Total	63

OPERATIVE TECHNIQUE

The skin incision was made laterally from below the trochanteric region extending in a curve to a point distal to the patella In *43 cases* the tractus ilio-tibialis was detached laterally in its axial direction and severed from its insertion at the lateral condyle of the tibia after which the tractus was rotated 180 degrees on its axis and fastened with silk or supramid sutures to a bony pocket made for this purpose in the patella and with some further sutures to the quadriceps tendon The flap of tendon and periosteum formed when the bony pocket was cut out was sutured over this site of attachment (Figs 4–7)

In the other *20 cases* the tractus was entirely detached that is laterally as well as ventrally in its axial direction and from its attachment It was transposed in its plane and fastened with its end either split or intact to a similar bony pocket made in the patella with perforating supramid or silk sutures which passed through the ligamen



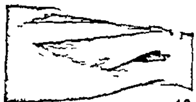


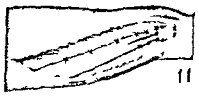












Figs 4–7

The tractus ilio tibialis has been *transposed by rotation* and fastened to the patella Fig 4 the skin incision has been made laterally extending in a curve distally of the patella Fig 5 the tractus ilio tibialis has been detached laterally and distally Fig 6 the tractus is rotated 180 degrees around its longitudinal axis Fig 7 the tractus has been fastened to the patella

Figs 8–11

The tractus ilio tibialis has been *transposed in the same plane* and with its end split fastened to the patella Fig 8 the tractus has been entirely detached laterally as well as ventrally in its axial direction and also from its attachment Fig 9 the detached end portion of the tractus has been split Figs 10 and 11 with supramid suture which perforate the ligamentum patellae the ends of the tractus are fastened into a bony pocket made in the patella

tum patellae The flap of tendon and periosteum was sutured over the site of attachment (Figs 7–11)

Sufficient attention must be paid to adequate dissection of the tractus which should comprise fibres setting out both from the musculus tensor fasciae latae and from the gluteus maximus The tractus should not be divided above its site of attachment but at its insertion to ensure that its length is adequate for transposition and thus to prevent tension The fascia intermusculare was severed A subperiosteal attachment to the patella is not considered a sufficient measure but the tractus is fastened to a bony pocket made in the patella A superficially fastened tractus may easily become loosened at a later stage *e g* in connection with a small injury or stumbling

In the present series the cases operated on according to the first operative technique described above have been followed up for a longer period the latter operative method having been more generally employed in recent years Transposition of the tractus by rotation is a comparatively simple measure whereas transposition in the same plane is more complicated The former method leads to a cosmetically more satisfactory result while a tractus ilio-tibialis transposed in the same plane may form a fold on the anterior upper surface of the thigh when the sitting patient extends his knee joint However the latter method gives a better functional result In the present material there are more failures among the cases in which transposition was done by rotation of the tractus but the varying periods of observation exclude definite conclusions The operative method has been decided upon *in casu* since for instance in marked contracture of the musculus tensor fasciae and the tractus ilio-tibialis it is better to perform transposition by rotation

PHYSIOTHERAPY AND POSTOPERATIVE CARE

In most cases physiotherapy aiming at correction of fixed deformities was commenced prior to operation and when necessary a corrective plaster cast was applied to reduce the deformity (particularly flexion contracture) After the operation the extremity was immobilized for 3 to 4 weeks (by means of a posterior splint or a plaster bandage) with the knee joint at maximum extension and the hip-joint in slight flexion Physiotherapy was started one week after the operation with exercises for the tensor muscle training of the knee joint and walking exercises were commenced after termination of immobilization When there was

a marked flexion contracture of the knee joint Kreutz s splint was applied nightly for a couple of months after the period of immobilization

RESULTS

In evaluating the results of the present analysis of cases the following points have been considered

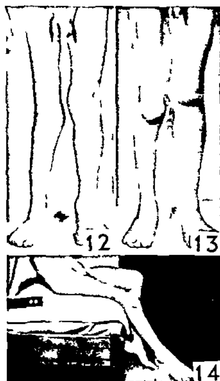
1 Has the extension power of the knee joint increased and if so by how much?
2 Does the knee joint feel more stable when walking and has limping been reduced or disappeared entirely? Is it necessary for the patient to have recourse to hand to knee walking?
3 Is the deformity completely or partly corrected?
4 Ability to walk without braces crutches or walking stick
5 The patient s own opinion on the result of the operation
6 The results of the clinical examination before operation and at the latest follow up examination

On the basis of these factors the results can be classified as follows

Scale

Very good	The extension power of the knee joint has increased considerably and the knee has gained in stability and/or the deformity has been corrected and/or the patient could discard his braces and/or crutches.
Good	The extension power and stability of the knee joint have increased and/or the deformity has been reduced and/or the patient could discard his crutches and/or his braces or he could manage with smaller brace than before
Fair	The stability of the knee joint has increased and the extension power of the knee joint has increased somewhat The deformity has been corrected to some extent The patient can use a walking stick in place of his crutches and believes that the condition has improved
Unaltered	No improvement in the condition or function of the knee could be established apart from increased stability In the patient s opinion the operation did not improve the function of the knee joint or his ability to walk
Impaired	The patient had to resort to brace or crutches as a result of the operation and/or deformity of the knee has recurred or increased

Very good and good results were observed in a total of 42 out of the 63 cases which makes 66 6 per cent of the whole series (Figs 12 30) In 12 cases the condition was classified as unaltered There were no cases of impairment in the present series i e no patient was compelled

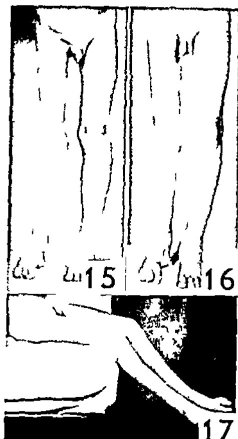


Figs 12–14

Case 58 – Fig 12 patient aged 6 years photographed 5 years after paralysis Extension power of the knee joint = 1 genu valgum and external rotation of the tibia Figs 13 and 14 condition *1 year after operation* in which the tractus was *transposed by rotation* to the patella *The deformity has been corrected* extension power of the knee joint = 2 3

TABLE 6
Results

	No of cases	Per cent
Very good	21	33.3
Good	21	33.3
Fair	9	14.3
Unaltered	12	19 1
Impaired	0	–
Total	63	100

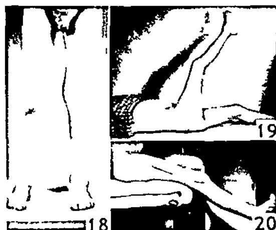


Figs 15–17

Case 61 — Fig 15 patient aged 6 years photographed 4 years and 6 months after paralysis Extension power of the knee = 1 genu valgum flexion contracture of both the knee—and hip joint the tibia rotated outward contracture of the tractus ilio tibialis Figs 16 and 17 the condition 6 *months after the operation* The tractus was *transposed in the same plane* and fastened to the patella The *deformity has been considerably corrected extension power of the knee* = 3

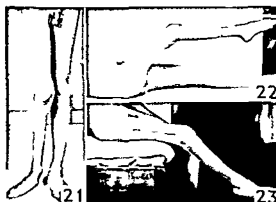
to resort to a brace or crutches on account of the operation No deformities of the knee joint had resulted from the operation nor were there any instances in which preoperative deformities had increased

Classifying the results according to the clinical symptoms (Table [illegible]) increased extension power of the knee joint was noted in 48 cases out of 63 and higher stability of the knee joint in 53 cases As will be seen from tables 6 and 7 some of these cases have been recorded as unaltered since the improvement was slight and the hoped for results were not achieved



Figs 18–20

Case 52 —Fig 18 Patient aged 4½ years photographed 3 ½ years after paralysis *Extension power of the knee 2–3* flexion contracture of the knee and hip joint the tibia is rotated outwards contracture of the tractus ilio tibialis Figs 19 and 20 condition *3 months after operation* The tractus has been transposed in the same plane to the patella *The deformity is already corrected extension power of the* knee = 4



F gs 21 23

Case 60 —Fig 1 patient aged 6 years ph tographe l 5 years after paralysis *Exten s n pou r of the knee* = 2–3 bef re the operati n the patient u ed a *l ng brace n his right extremity* the typ cal d f rmity of the extremity was cau ed b c n tracture f the tractu ili tibiali Fig 2 and 23 condition 5 ½ m nth after p rati n The tractus ha been tran po ed in the same plane t the patella *The d f rmity has been almost completely corr cte l the long brace has b en exchang l f r a per neal brac* extensi n power f the knee = 3

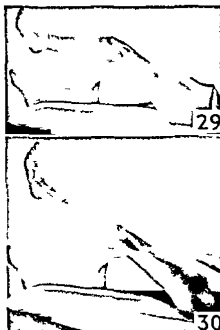


Figs. 24–28

Case 51.—Figs. 24 and 25: patient aged 6½ years, photographed 3 years after paralysis. Before the operation the patient was able to *stand with crutches but not more.* Extension power of the left knee = 1. Both lower extremities exhibited *deformities* due, among other things, to contracture of the tractus. Figs. 26–28: condition 1 year and 4 months after operation. In the left extremity the tractus was transposed in the same plane to the patella. In the right extremity the tensor muscle was transposed to the symphysis. *Walks comparatively well on crutches and without braces on the left limb. The deformity in the left limb is almost completely corrected.* Extension power of the left knee = 3.

CAUSES OF FAILURE

In 12 cases the condition remained unchanged and the factors responsible for the failure of the operative procedure in these cases are given in Table 8.



Figs 29 and 30

Case 43 —Patient aged 3 years photographed 1? *years after operation* The tractus was transposed by rotation and fastened to the patella *Extension power of the knee = ? before operation The patient used walking stick when moving* there was no deformity *Since operation extension power of the knee = 4 The patient does not use walking stick and the stability of the knee joint is good* Flexion of the knee joint normal

TABLE 7

Results classified according to clinical symptoms

Symptoms	No of cases	Per cent
Increased extension power of the knee joint	48 63	76 ?
With higher stability of the knee joint	53 63	85 0
Completely corrected or reduced deformity	27/36	75 0
The patient was able to discard his brace and/or crutches	17/25	68 0
The patient was able to discard his walking stick	6 6	100 0

In the individual cases the following factors contributed to the failure

Failure of the operative technique

In the *first* case the transposed tractus had become completely detached from the patella In the *second* and *third* case the tractus was partly detached and tractus

fibres were still palpable on the tibial condyle *i e* only part of the tractus had been transposed while part remained in its former site In the *fourth* and *fifth* cases part of the tractus also remained in its former site and the tractus had not been detached high enough as could be deduced from the shortness of the incision In the *sixth* case the preoperative physiotherapy had been inadequate and the flexion contracture had not been corrected In this case the detachment of the tractus was also inadequate

Incorrect indications

In the *first two* cases the muscular function of the extremity was too poor the power of the tensor muscle being only 1 and there was no deformity In the *third* case 41 years had elapsed since the onset of the illness and there was a marked deformity of the joint (25 degrees of valgus 30 degrees of recurvatum) the power of the tensor muscle being only 2 In the *fourth* case the muscular function of both extremities was practically nil and the patient walked with crutches the power of the tensor muscle being 2 to 3

Other diseases

In the *first* case arthrodesis of the knee had been performed for severe osteoarthritis three years after transposition of the tractus In the *second* case the patient underwent supracondylar osteotomy six years after transposition of the tractus which caused impairment of the primarily good result this information was obtained from the case record

TABLE 8
Causes of failure in 12 cases

Cause	No of cases
Errors in operative technique	6
Indications misjudged	4
Another disease	2

DISCUSSION AND CONCLUSIONS

It is to be noted that the series does not comprise any impaired cases or any complications On the other hand there are reports giving comparatively high percentages of impaired cases after transposition of the hamstrings (*cf* 3 6 11) *E g* *Schwartzmann & Crego* reported recurvatum of the knee joint at a late stage in 16 per cent of their cases despite good primary results after transposition of the biceps femoris alone (3 11) after the same operation lateral dislocation of the patella had resulted in 29 per cent of cases It should be possible however to avoid the latter by performing the transposition by the medial route (2) Recurvatum of the knee joint was further established in 23 per

cent of cases after simultaneous transposition of both the biceps femoris and semitendinosus (11)

In view of these reports on transposition of the hamstrings and considering the results obtained in the present series of cases the transposition of the tractus ilio tibialis to the patella and utilization of the musculus tensor fasciae latae is thought to be a suitable and justified method of operation in the treatment of quadriceps paralysis and certain deformities of the lower extremities caused by contracture of the tractus ilio tibialis subsequent to poliomyelitis

To obtain good operative results a careful selection of patients and a good operative technique are imperative The muscular power of the musculus tensor fasciae latae must be sufficient since it was observed in some cases that it diminished somewhat after operation Postoperative physiotherapy should be commenced sufficiently early Flexion contracture of the knee joint should be corrected as far as possible before the operation by means of physiotherapy and perhaps with a corrective plaster cast The power of the muscles of the hip joint does not seem greatly to affect the end results since good results are obtained in cases both with good and with poor muscle power At follow up examination the flexion of the knee was found to be limited in 9 cases though by less than 50 degrees which in itself does not constitute a major functional disturbance This should be taken into consideration when the tractus is fastened to the patella

Particularly suitable for transposition of the tractus ilio-tibialis to the patella are cases in which there is a comparatively powerful tensor muscle and a deformity of the knee joint following contracture of the tractus (genu valgum flexion contracture of the knee joint and of the hip external rotation of the tibia) In children and adolescents it is easier to achieve a favorable result Likewise it is established that a taut tractus ilio tibialis has an inhibiting effect upon the growth of the lateral margin of the proximal tibial epiphyseal line Mild cases of paralysis are favourable and when some of the power of the quadriceps muscle is preserved the result in carefully selected cases is good Little benefit is obtained when the paralysis comprises the entire limb or is of severe degree with the exception of those cases in which there is contracture of the tractus In these rare cases considerable improvement is achieved by mere fasciotomy

By transposing the tractus to the patella and thus making use of the tensor fasciae latae muscle one must not expect to achieve full extension of the knee joint since the tensor muscle is too short for this

movement For the function of the knee this is not in itself an important factor or at all necessary for the stability of the knee joint (cf 4) However the power of extension of the knee joint can be taken as one criterion when evaluating the condition before and after operation

SUMMARY

The treatment of paralysis of the quadriceps muscle and certain deformities of the lower extremity following contracture of the tractus ilio tibialis with its allied structures after poliomyelitis is reviewed on the basis of 63 cases of transposition of the tractus ilio tibialis to the patella The average follow up period was 7 years

It is stressed that the tractus ilio tibialis should be dissected sufficiently far near to the trochanteric region and the tractus to be transposed should include the fibres setting out from both the tensor muscle and the gluteus maximus Subperiosteal fixation to the patella was not considered firm enough and osseal fixation was therefore preferred

Excellent results were noted in 21 out of 63 cases (33 3 per cent) Considerable improvement had occurred in a further 21 cases (33 3 per cent) Some improvement had occurred in 9 out of 63 cases (14 3 per cent) In 12 cases the patient s condition was unchanged (19 1 per cent) In no case was impairment observed The reasons for failure in the 12 cases were in 6 cases an operative technical factor, in 4 cases misjudgement of the indications and in 2 cases the presence of another disease

The study of these 63 cases has indicated that transposition of the tractus ilio tibialis to the patella and utilization of the musculus tensor fasciae latae is a suitable method of operation in the treatment of quadriceps paralysis and some deformities (genu valgum knee flexion deformity and external rotation of the tibia flexion and abduction contractures of the hip) subsequent to poliomyelitis

RÉSUMÉ

Le traitement de la paralysie du muscle quadriceps et de certaines déformités des extrémités inferieures dues à la contracture du tractus ilio tibialis avec ses structures alliées à la suite de la poliomyélite a été passé en revue sur la base de 63 cas de transposition du tractus ilio-tibialis à la rotule La période moyenne d observation a été de 7 ans

Il est souligné que le tractus ilio tibialis doit être detaché assez loin près de la region trochantérienne et que le tractus à transposer doit

comprendre aussi bien les fibres qui partent du muscle tenseur que celles qui partent du gluteus maximus. La fixation subpériostale à la rotule n'a pas été considérée comme étant assez ferme et c'est pourquoi on a préféré la fixation osseuse.

D'excellents résultats ont été enregistrés dans 21 des 63 cas (33.3 %). Une amélioration considérable a été observée dans 21 autres cas (33.3 %). Une certaine amélioration est apparue dans 9 des 63 cas (14.3 %). Dans 12 cas la condition des malades est restée inchangée (19.1 %). Il n'y a eu d'aggravation dans aucun cas. Les raisons de l'insuccès dans ces 12 cas ont été les suivantes: dans 6 cas un facteur opératoire technique, dans 4 cas une fausse estimation des indications et dans 2 cas la présence d'une autre maladie.

L'étude de ces 63 cas a montré que la transposition du tractus ilio tibialis à la rotule et l'utilisation du muscle tenseur fascia lata est une bonne méthode d'opération dans le traitement de la paralysie du quadriceps et de certaines déformités (genu valgum, déformités de flexion du genou et rotation externe du tibia, contracture de flexion et d'abduction de la hanche) subséquentes à la poliomyélite.

ZUSAMMENFASSUNG

Über die Behandlung der Lähmung des M. quadriceps und gewisser Deformitäten der unteren Gliedmassen als eine Folge der Kontraktur des Tractus ileo tibialis und der mit ihm verbundenen Geweben wird auf Grund von 63 Fällen von Transposition des Tractus ileo tibialis auf die Kniescheibe berichtet. Die durchschnittliche Beobachtungszeit betrug 7 Jahre.

Es wird hervorgehoben, dass der Tractus ileo tibialis genügend weit proximal bis in die Trochantergegend präpariert werden sollte und dass der zu transponierende Tractus sowohl die vom Tensor Fasciae als auch die vom M. gluteus maximus kommenden Fasern einschliessen sollte. Subperiostale Fixation an der Patella wurde nicht als ausreichend angesehen und die ossale Fixation wurde deshalb vorgezogen.

Ausgezeichnete Ergebnisse wurden bei 21 von 63 Fällen beobachtet (33.3 %). Bedeutende Besserung wurde in weiteren 21 Fällen gefunden (33.3 %). Mässige Besserung wurde bei 9 von 63 Fällen gesehen (14.3 %) und in 12 Fällen war der Zustand unverändert (19.1 %). In keinem Falle wurde eine Verschlechterung beobachtet. Die Gründe des Misserfolges in den 12 Fällen waren: In 6 Fällen ein operativ technischer Faktor, in 4 Fällen eine unrichtige Indikationsstellung und in

2 Fällen das Vorhandensein einer anderen Erkrankung Das Studium dieser 63 Fälle zeigt dass die Transposition des Tractus ileo-tibialis auf die Patella und Benutzung des M tensor fasciae latae eine brauchbare operative Methode zur Behandlung der Quadricepslähmung und einiger Deformitäten (genu valgum Knie Beugekontractur und Auswärtsdrehung der Tibia Flexions- und Abduktionskontrakturen der Hüftgelenke) im Gefolge der Poliomyelitis ist

REFERENCES

1 *Broderick T F Reidy J A & Barr J S* Tendon transplantations in the lower extremity A review of end results in poliomyelitis II Tendon transplantations at the knee J Bone and Joint Surg 34 A 909 1952

2 *Caldwell C D* Transplantation of biceps femoris to the patella by the medial route in poliomyelitic quadriceps paralysis J Bone and Joint Surg 36 A 1296 1954

3 *Crego C H & Fischer F J* Transplantation of the biceps femoris for the relief of quadriceps femoris paralysis in residual poliomyelitis J Bone and Joint Surg 13 515 1931

4 *Debrunner H* Die Behandlung der Quadricepslähmung Zeitschr Orthop [illegible] 164 1940

5 *Erlacher P* Lehrbuch der praktischen Orthopädie Wien – Bonn 1955

6 *Centa V* Transplantations of flexors (hamstrings) tendons to the patella in poliomyelitic paralysis of the quadriceps Arch Chir Orthop 33[illegible] 1956

7 *Hagelstam L* Muscle and tendon transplantations in the lower limb in poliomyelitis Acta Orthop Scandinav 27 49 1958

8 *Hodkinson R* Contracture of tensor fasciae latae in old poliomyelitis J Bone and Joint Surg 39 B 595 1957

9 *Irwin C E* The iliotibial band its role in producing deformity in poliomyelitis J Bone and Joint Surg 31 A 141 1949

10 *Ober F R* Tendon transplantation in the lower extremity New England J Med 209 52 1933

11 *Schwartzmann J R & Crego C H* Hamstring tendon transplantation for the relief of quadriceps femoris paralysis in residual poliomyelitis J Bone and J Surg 30 A 541 1948

12 *Spitzy H* Neue operative Wege in der orthopädischen Chirurgie Wien Med Wchr 77 1406 1924

13 *Spitzy H* Natürliche und künstliche Bandmuskelbildung Zeitschr Orth Chir 46 111 1925

14 *Stern H* Some experiences of transposition of the hamstrings in paralysis after anterior poliomyelitis Proc Acta Orthop Scandinav [illegible]

15 *Yount C C* The role of the tensor fasciae femoris in certain deformities of the lower extremities J Bone and J Surg 8 171 1926

16 *Yount C C* An operation to improve function in quadriceps paralysis J Bone and Joint Surg [illegible]0 314 1938

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CIRCULATION OF AMPUTATION STUMPS

Arteriographic and Skin Temperature Studies

By

U. Erikson and A. Hulth

Pain in amputated limbs is very common. But there are no reliable data on the incidence of such pain in clinical series classified according to the indication for amputation and the type of the pain. The discomfort experienced by amputees may vary in character. Sometimes its cause is obvious, as that resulting from a poorly fitted prosthesis or from infection of the skin or stump, and relief is readily afforded. There is also pain of more obscure derivation. Two types can be distinguished, which may occur singly or in combination. One is the phantom pain strictly limited to the phantom limb, usually to part of the hand or foot, and invariably recurring in the same situation and with the same character in the individual patient. Persons suffering from this type of pain are usually able to describe it distinctly. The other type is the stump pain, which may occasionally be very severe but which is not rigidly delimited. This is more of the character of causalgic pain (*Leriche* 1950).

The pathogenesis of the pain is largely unknown. *Leriche* (1950) believed the origin of phantom pain to be changes in the severed spinal nerves, such as amputation neuroma and more general nervous lesions. Stump pain, on the other hand, he maintained to be of sympathetic derivation. It is *Leriche*'s school, in particular, which holds the cause of the pain to be pathologic changes of different types in the stump. Others regard it as of central derivation. *Leriche* demonstrated hypervascularization in stumps giving stump pain in some cases, but did not specify the number of patients examined or the arteriographic technique used. Some animal experiments have shown a similar tendency

to hypervascularization of amputation stumps, as reported by *Abeatici & Ferrero* (1953), *Hulth & Olerud* (1962) and others. On histologic examination *Ferrero & Abeatici* (1953) found hyperplasia of nerve fibres in vascular walls and connective tissue. There is then much to suggest that neurovascular changes in the soft tissues of the stump give rise to pain. Apart from *Leriche's* studies, no investigations of the vascular changes in amputation stumps in human subjects have been published. But numerous psychiatric studies of amputees are on record (*Cronholm* 1951, *Haber* 1956, *Simmel* 1958, and others). However, such investigations have been directed chiefly to phantom limb—the sensation that the amputated part of the extremity is still there—which is an extremely common phenomenon. *Loon* (1960) described oscillometric and temperature studies carried out by Ellen Brown. The oscillometric determinations showed the pulse amplitudes to be lower in the amputated than in the sound limb, and the amputation stump was also almost invariably colder than the corresponding point of the intact side. Ellen Brown found no correlation between the severity of the phantom or stump pain and the temperature recorded.

We believed it to be of interest to study in closer detail the vascular changes demonstrated in the soft tissues of amputation stumps by *Leriche*, and to correlate the findings with the clinical analysis of the patient's symptoms; we also carried out simple skin temperature determinations while raising body temperature.

MATERIAL AND METHODS

The patients in the present series underwent amputation for injury or tumour. Those amputated for vascular disorders were not included in the investigation, since the method of examination was in part founded on comparison of the amputated limb with a sound fellow in which the vessels were supposedly healthy. The patient's symptoms were closely analysed as regards the presence of pain, its incidence and nature.

Arteriography was performed by femoral puncture and the injection of 20 ml. of 60 per cent Urografin by hand. The injection was made in the retrograde direction in order to facilitate the mixture of contrast medium and blood. A film changer was used, one exposure being made per second for approximately 25 seconds. In cases of lower leg amputation both the thigh and the distal stump were examined roentgenographically. The examination in most cases elicited pain or a sensation

of warmth which was in some instances fairly severe The discomfort was short lived and was found to correspond in time with the arterial phase of the arteriogram It was situated in the amputated leg in its entirety or in a few instances to only part of the amputation stump Thirty one patients were examined arteriographically in this manner

Temperature was measured with a thermoelectric apparatus electrodes being placed as follows 1) a skin electrode on the medial side of the stump approximately 10 cm above its free end 2) a skin electrode on the stump end 3) a skin electrode at a point corresponding to (1) on the sound leg 4) a skin electrode on the big toe of the intact leg and 5) and 6) muscle electrodes on the lateral side of the stump approximately 10 cm above its free end and at a corresponding point on the other leg The muscle electrodes served for reference Before determining temperature the patient lay with uncovered legs for between 20 and 30 minutes When the temperature readings at five minute intervals had become stabilized the body including the arms was covered with a large electric blanket A thick sheet was interposed between the blanket and the body for protection against burns The patient s symptoms if any were recorded at each reading In some instances 1 ml of dihydro ergotamine was given to hasten the vasodilatation Altogether 24 patients were examined in this manner all except two of whom also underwent arteriography

RESULTS

Altogether 33 patients were examined with one or both of the two methods described above Of these 16 were wholly asymptomatic and walked well with their prostheses Nine suffered from constant disabling pain stump pain in three cases phantom pain in five and a combination of both in one case The symptoms in the remaining nine cases were not so severe as to be disabling but consisted in slight or more marked—but intermittent—pain The intermittent pain was associated with weather changes or occurred on removing the prosthesis at night or " at any time None of the patients amputated in childhood or up to the age of 20 years had any pain (seven were under 20 years)

The arteriographic appearances varied fairly widely but a schematic classification into groups was possible In one of the groups the arteriograms showed the arteries to be tortuous in some cases of fine calibre and forming a dense network in part or the whole of the amputation stump Compared with the rest of the amputated limp and with the



Fig. 1
Male, 59 years, amputated in 1918. Arteriography 1960. Pain and tenderness in the amputation stump. Tortuosity of both arteries and veins serving muscles.

corresponding portion of the other leg the appearances were those of hypervascularization. In a small number of other cases in this group the arteries were likewise tortuous but they did not form so dense a network and were wider peripherally (Figs. 1 to 4).

The arteriographic appearances described in the preceding section were seen in the present series in patients suffering from pain of the stump or phantom type (Table 1). Three of the 31 patients examined arteriographically were excluded since the examination was performed very soon after the amputation. Hypervascularization of the stump was however present in four patients without pain: two who had undergone high amputation and in whom the injury necessitated skin grafting over the greater part of the thigh; a third in whom both legs had been amputated below the knee 44 years earlier, both stumps being infected and showing navel-like gathering; and a fourth in whom the skin was in poor condition and the soft tissues excessive.

One patient who had undergone bilateral amputation had pain in one but not in the other leg. In the painful leg there was local hypervascularization and a highly ramified venous network corresponding to the hypervascularization distal to the fibular end.

In the other main group of patients vascularization was sparse, the



Fig 9
Male 55 years amputated 1958 Arteriography 1960 Very intense causalgic stump pain Large number of spiralled muscle vessels

vessels narrowed uniformly peripherally and showed no tortuosity In these cases the vessels appeared to be adapted to the amputation stump (Fig 5)

This group of patients in whom vascularization was sparse and the vessels showed no tortuosity included none with any form of discomfort whatever

Occlusion of the popliteal artery was demonstrable in three cases Two of these patients had phantom pain and in addition to the occlusion hypervascularization with narrow and tortuous arteries distally in the stump The third patient had neither pain nor hypervascularization of the stump

The patient with slight or intermittent pain all exhibited vascular changes of varying degree which were however not definitely related to the severity of the pain



Fig. 3



Fig. 4

Fig. 3. Male, 47 years, amputated in 1955 and reamputated for pain in 1958. Arteriography 1960. Intense pain persists in the phantom limb. Numerous tortuous arteries, especially on the fibular side.

Fig. 4. Male, 65 years, amputated in 1959. Arteriography 1960. Very intense phantom pain. Numerous spiralled arteries.

TABLE 1

Arteriographic Findings in 31 Amputated Limbs

	Hypervascularization + tortuosity of wide vessels	Arteriosclerotic occlusion	Normal
No pain, skin good		1	12
No pain but infection or skin grafting	4		
Moderate pain	5	1	
Disabling pain	6	1	1(*)

(The table includes 28 patients, three of whom underwent bilateral amputation. One of the bilateral amputees had pain in only one limb, where there was local hypervascularization.)



Fig. 5.
Female 17 year, amputated in 1951 for a fibrosarcoma on the lower leg. Arteriograph 1960. No symptom. Normal vascular ramifications.

Measurement of skin temperature gave the following results: as a rule the temperature of the skin on the stump was lower than at the corresponding level on the sound leg. In 9 of 24 cases the skin temperature on the stump was higher than on the other side. This difference was not related to the presence of absence of pain. On raising body temperature a difference was, however, found between patients experiencing phantom pain during the experiment and those who did not do so. Phantom pain was present or developed when body temperature was raised in nine patients; in eight of them the skin temperature on the stump rose distinctly (more than 2° C), while at the corresponding level on the intact leg it rose only in one instance. In the remaining case a steep fall in skin temperature on the stump was associated with the onset of severe phantom pain. The popliteal artery was occluded in this case. In only four of 15 patients in whom no phantom pain developed during the warming process did the skin temperature on the amputation stump rise. Figs. 6 to 9 illustrate these temperature curves. Muscle temperature was in the great majority of cases lower on the amputated than on the sound side, and did not alter when body temperature was raised.

95 07 12
left leg amputated
below knee

36
35
34
33
32
31
30
29
28
27
26
25

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 MINUTES

Fig 6

Skin temperature curve in a 65 year old man with severe phantom pain (same patient as the arteriogram in Fig 4) On raising body temperature the skin temperature on the amputated limb rises steeply but remains stationary on the intact side

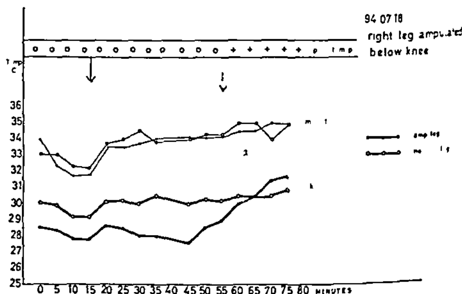


Fig 7

Skin temperature curve in a 66 year old man with severe phantom pain Marked elevation of skin temperature on the amputated side coincide with the onset of phantom pain

16/1-61

1709 03
the right leg amputated
below-knee

0 5 10 15 20 25 30 35 40 45 50 55 60 MINUTES

Fig 8

Skin temperature curve in a 16 year old youth free from symptoms
Slight rise on the stump end but not elsewhere on the stump

440802
right leg amputated
through knee

0 5 10 15 20 25 30 35 40 45 50 55 60 MI UTES

Fig 9

Skin temperature curve in a 43 year ld man without pain
[illegible] n the amputated side

DISCUSSION

The arteriographic and skin temperature studies were carried out in a series of patients in whom amputation was indicated by injury or tumour The vascularization of the stumps was found to be profuse sparse or of an intermediate form In some instances the arteriographic appearances were probably pathologic consisting in sinuous vessels and persisting venous networks Pathologic vessels of this type were seen only in patients with pain In those without any form of discomfort the vascularization was as a rule sparse—unless skin infection was present or the stump had been treated with skin grafts Skin temperature measurement showed the skin of the stump to rise in temperature when body temperature was raised in patients with phantom pain while in those without current phantom pain the skin temperature usually did not rise

In a clinical series of this type classification into groups must be regarded with some reserve since it is founded on the discomfort reported by the patients But two distinct main groups could be distinguished one in which no pain whatever was reported and one in which pain was so severe (of phantom or stump type) that the patients were unfit for work for long periods or permanently Some of the patients in this latter group were even unable to wear their prostheses There was also an intermediate group in which the pain was slighter or only intermittent but not so severe as to prevent work On relating the arteriographic findings with this clinical classification a definite predominance of hypervascularization with vessels of pathologic appearance is found in the group with disabling pain The wholly asymptomatic group on the other hand was found to have what might be called normal vascular ramification—that is the number of vessels appeared to be adapted to the tissues to be supplied and their calibre narrowed uniformly However there were exceptions in both groups and a larger series would be required to confirm the observations in the present study Skin temperature determination gave results which could be correlated with the incidence of phantom pain during the body warming process

Many factors have to be taken into consideration when attempting to interpret the vascular phenomena demonstrated in the present study It seems unlikely that the abnormal vascularization and skin temperature reactions are anything more than manifestations of altered metabolism in the tissues of the amputation stump The hypervascularization does not necessarily imply that the circulation is adequate but

should rather be interpreted as an incorrectly adapted cirkulation There might be changes in vascular tone due to substances acting upon the vessels both those of normal occurrence and pathologic metabolites such as for instance polypeptides Finally but not least important consideration must be given to changes in innervation due to amputation neuroma hyperplasia of the autonomic nervous system and the like

SUMMARY

Thirty three persons amputated for injury or tumour were examined with arteriography and skin temperature measurement after warming the body Amputees with symptoms such as phantom pain or stump pain differed from those suffering no pain in the former group the stumps were found to show hypervascularization the vessels frequently being tortuous Patients experiencing pain during the body warming process also exhibited a rise in the skin temperature on the stump

RESUME

Trente trois personnes amputees par suite de lesions ou de tumeurs ont ete examinees par arteriographie et controle de la temperature de la peau le corps ayant ete rechauffe Les amputes avec des symptomes tels que douleurs fantomes ou douleurs dans le moignon different de ceux qui ne souffrent d aucun symptome dans le premier groupe on a trouve une hypervascularisation des moignons les vaisseaux etant frequemment tortueux Chez les malades eprouvant des douleurs durant le processus de rechauffement du corps il y avait aussi une elevation de la temperature de la peau du moignon

ZUSAMMENFASSUNG

Drei und dreissig Personen die wegen Verletzungen oder Tumoren amputiert *worden waren wurden mittels Arteriographie und Haut*temperaturmessungen nach Erwarmung des Korpers untersucht Amputierte die and Phantomschmerzen oder Stumpfschmerzen litten unterschieden sich von denen die keine Schmerzen hatten In der ersten Gruppe zeigten die Stumpfe Hypervaskularisation und die Gefasse waren oft gewunden Patienten die Schmerzen wahrend der Erwarmung des Korpers angaben zeigten auch eine Erhohung der Hauttemperatur am Stumpf

REFERENCES

Abeatici S & *Ferrero R* Studio arteriografico dei monconi d amputacione (ricerche sperimentali) Minerva Chir *8* 459 1953

Cronholm B Phantom limbs in amputees Acta psych et neurolog scand. Suppl. 72 1951

Ferrero R & *Abeatici S* Su alcuni aspetti istologico dell innervazione arteriose nei monconi d amputazione (ricerche sperimentale) Minerva Chir *8* 595 1953

Haber W B Observations on phantom limb phenomena Arch neurol psych. *75* 624 1956

Hulth A & *Olerud S* Studies on amputation stumps in rabbits J Bone and Joint Surg *44 B* 431 1962

Leriche R Etude critique des mecanismes de la douleur chez les amputés Journal de Chirurgie *66* 5 1950

Loon H F Biological and biochemical principles in amputation surgery Prosthetics International Copenhagen 1960 pp 41–48

Simmel Marianne L The conditions of occurrene of phantom limbs Proc Amer Philosoph Soc *102* 492 1958

EDITORIAL

This volume is dedicated to *Sten Friberg* and *Gunnar Wiberg*, both of whom are celebrating their 60th anniversary this year.

Sten Friberg succeeded *Patrik Haglund* and *Henning Waldenstrom* to become the third professor of Orthopaedic Surgery at the Karolinska Institutet in Stockholm, this being the first chair in Orthopaedics instituted in Scandinavia.

Gunnar Wiberg is the first holder of the second Orthopaedic Professor's chair in Scandinavia; this was instituted in Lund in 1947. Since that time another seven chairs have come into existence, two in Denmark, one in Finland, one in Norway and three in Sweden.

Sten Friberg and *Gunnar Wiberg* had their Orthopaedic training with *Henning Waldenström*.

The accelerated evolution of Orthopaedics as a medical speciality can to a significant measure be attributed to both of them. Their achievements are also shown by the development of Acta Orthopaedica Scandinavica over the last 15 years, a period during which *Sten Friberg* has been Editor and *Gunnar Wiberg* one of the Swedish redactores. During this period the issue of the journal has increased five fold. As a result of *Sten Friberg's* and *Gunnar Wiberg's* many international contacts the third meeting of the SICOT after World War two was held in Stockholm in 1951.

This volume contains contributions from Swedish Orthopaedic surgeons who had their training at the Orthopaedic Clinic of the Karolinska Institutet in Stockholm and the Orthopaedic Clinic in Lund. In addition a number of distinguished friends from different parts of the world have contributed. The interest displayed in this birth day volume shows a high esteem of *Sten Friberg's* and *Gunnar Wiberg's* achievements in Scandinavian and International Orthopaedic work, which we hope will continue for many future years.



STIAN FRIBERG

5 – 9 – 1902



GUNNAR WIBERG

24 - 11 - 1902

WIDER RESPONSIBILITIES IN ORTHOPAEDICS

By

H J SEDDON
London

The purpose of this short paper[1] is to discuss the position of orthopaedics in countries where the evolution of this branch of surgery is still in progress There are many of them but they are mostly in Asia and Africa My personal knowledge of what is happening is patchy because most of my observations have been made in countries that are parts of the British Commonwealth so of necessity examples cited are taken from them At the outset I must ask the reader not to infer that the state of affairs in some Commonwealth countries is peculiarly unsatisfactory on the contrary I suspect that conditions in underdeveloped countries generally are on the average less favourable Indeed it was the splendid work of orthopaedic surgeons throughout the Commonwealth that impelled me to devote part of the *Robert Jones* Lecture in 1961 (Journal of Bone and Joint Surgery 34 B 425) to describing their achievements

Specialisation in medicine is related to the ratio of doctors to population more doctors more specialisation In Europe it is about 1 900 in Asia about 1 6500 in Africa about 1 9000 Not all of these doctors are directly concerned with the care of the sick and the distribution of those who are is very uneven I know parts of West Africa where there is one doctor for every 25 000 people In India the *aim* of the government is to provide one doctor for every 70 000 inhabitants of the vast rural areas

Unfortunately though understandably it is in the very countries where specialists are so thin on the ground that the need for their services is greatest Diseases which in western countries have been

[1] The invitation to contribute to this Festschrift in honour of my friend *Sten Friberg* and *Gunnar Wiberg* reached me during the course of a teaching tour in India Without access to records and books it was impossible to write a scientific article However the Editor has allowed me to discuss a general topic which I hope the reader will not find devoid of interest *H J S* Srinagar Kashmir

brought under control are still extremely prevalent Poliomyelitis and tuberculosis are striking examples Shortage of doctors means that every surgeon has to be good at everything surgical a really versatile general surgeon Yet the complexity of many of the cases coming to him and notably in orthopaedics would test the ability of a most experienced specialist Thus with joint tuberculosis for example at a time when methods for treating this disease have improved so remarkably the means for applying them where they are needed most are lacking or at best very deficient

Orthopaedics happens to be singularly important In Africa it accounts for about *40* per cent of *all* surgery the same is true of *India* And orthopaedics particularly in the two great continents is largely concerned with children and young adults in terms of life and usefulness it yields a good return

In the little kingdom of Jordan there is one orthopaedic surgeon In Northern Nigeria with a population of 19 millions there is one assisted year by year a number of the junior staff of my own hospital In the capital city of an Indian state with a population well over that of the British Isles there is one orthopaedic surgeon at the 1 000 bed teaching hospital There is more than enough to occupy him there but in addition he has 50 beds for osteo articular tuberculosis in the 600 bed sanatorium The patients with Pott s paraplegia—I saw seven in a row in one ward—had of necessity to be treated conservatively in the first place because there were not enough hours in the week for operating on all but those who failed to recover spontaneously Thus valuable beds were wasted This picture painted perhaps in lighter or darker shades can be repeated almost endlessly

I recall discussions that took up two long hot afternoons in an African capital where a surgeon had started a clinic for children who had had poliomyelitis and were coming from all over the country We reluctantly reached the conclusion that with the available resources it was not justifiable to do more than correct contractures of the lower limbs (the like of which is now rarely seen in Western Europe) fit the patients with simple inexpensive appliances and so *put them* into their feet Reconstructive surgery for the hands of patients with neural leprosy was another topic should they embark on this type of work? The answer was that this would have to wait children with poliomyelitis affecting the upper limbs being ahead of them in the queue because they had youth and normal cutaneous sensibility in their favour Working out priorities of this kind is a depressing exercise

Is it worth while trying to stem this apparently limitless flood of morbidity? An example from Hong Kong, where tuberculosis is rife, shows what can be done. There *Hodgson* has reported that since 1951 the annual death rate from osteo-articular tuberculosis has fallen from 325 (two thirds of the fatalities being in children under five years of age) almost to vanishing point.

The determining factor everywhere is poverty. Until recently fatalistic ignorance was sometimes responsible for failure to make full use of such medical facilities as there were. But with the spread of education and like a wave in advance of it the demand for what medicine has to offer has swamped the existing services. No country can afford to spend more than a modest proportion of its revenue on medicine if other equally important requirements—education, agriculture, animal husbandry, soil and water conservation, industrial enterprises and communications—are not to suffer. Uganda, commonly regarded as a prosperous country, spends 10 per cent of the funds at the disposal of its government (which the United Kingdom supplements each year by £1 million) on medical services. This works out at eight shillings a head a year. India spends six per cent, which amounts to three shillings a head a year. The United Kingdom spends four per cent, but this comes to 234 shillings a head a year.

And these pittances have to cover public health as well as curative services. It is in just these countries that scourges we have almost forgotten, malaria, sleeping sickness, smallpox, cholera and other enteric diseases, are active and controllable only by unremitting vigilance. What is remarkable is that the curative services achieve anything at all, and yet they do so, sometimes with distinction and always with an economy that rebukes the profligate expenditure of the West. Those confronted with this situation for the first time either see salvation in spending far more money, which is not available, or leaving the curative services as a token force, the main effort and expenditure being concentrated on preventive medicine. There is something to be said for the latter. In saving of life these mass production methods are cheap and effective, and it is true, too, that expenditure on curative medicine is a bottomless pit.

Yet even the most ardent exponents of preventive medicine have need of the clinical arm. A district cannot be cleared of yaws except by treatment of infected individuals. The campaign against leprosy got nowhere until effective drugs for the treatment of the disease had been discovered and administered on a large scale. It is possible that tuber

culosis could be brought under control by BCG inoculation alone yet even in India it has been thought worth while to mount the impressive Madras experiment—sponsored jointly by the Government of India the World Health Organization and the Medical Research Council of Great Britain—which already seems to show that the established disease can be mastered by domiciliary drug treatment What the public health man deplores and rightly so is the squandering of resources on curative services beyond what a country can afford Rigidly controlled expansion is necessary

Thus the need for economy in the hospital services is very great The deployment of doctors is important In the Commonwealth territories of East and West Africa the policy for the vast areas outside the cities has been to give district medical officers wide command to pay them well and to supply a large subordinate staff for public health and for curative medicine alike Competence in public health is regarded as specially meritorious and rewarded accordingly In this way it is possible to make tolerably good provision on the basis of one doctor for every 15 000 people India has decided to have many more doctors and medical schools have been established all over the country there are now in all nearly seventy of them The aim as has already been said is to supply one doctor for every 70 000 people in the rural areas a much more modest provision than has been made in some of the more remote parts of Africa with fewer doctors in relation to the population Yet in India the ratio doctor/population is 1 6000 which means that more than nine tenths of the doctors are in the towns Most of India s 30 million people live in the countryside These observations are made simply to show that increasing the number of doctors in itself is no answer It is their distribution that counts this means state control However alien this may be to our conceptions of professional freedom intelligently planned distribution encourages the differentiation of functions on which the progress of medicine depends In the smaller units the government is bound to provide men skilled in the four primary requisites medicine surgery obstetrics and gynaecology and pathology in the larger ones the additional and hardly less important departments of paediatrics orthopaedics ophthalmology and radiology

Since the second World War we have gradually been learning to think as citizens of the world The United Nations Organization in spite of many faults is a great power for good and of its various agencies none has acquitted itself better than the World Health Organiza

tion In this great work Scandinavia has played a noble part Two Secretaries General of U N O were Scandinavians one of them a Swede lost his life in the course of duties that would have broken the spirit of lesser men In the field of international medicine the Scandinavians have distinguished themselves Their work in Korea for example is well known In orthopaedics Malaya owes a debt to A G Karlen who occupied the chair of orthopaedics in Singapore with great distinction from 1956 to 1961 The British conscious of the need for continuing a task by no means half done established a new governmental agency last year called the Department of Technical Co-operation It became responsible for services formerly provided by the Colonial Office such as education medicine and agriculture but its activities are not to be limited entirely to countries within the British Commonwealth though these will head the list Under the Colombo Plan Britain Australia and New Zealand have already done excellent work in South East Asia There is indeed as with the great missionary movement of the 19th century an almost embarrassing proliferation of agencies

In the field of medicine certain clearly defined lines of action are emerging Putting them into effect depends ultimately on the vision goodwill and energy of senior men in medical schools without their co-operation little can be done This above all is the reason for this essay Here are the crucial points

1) Material aid in the form of buildings or equipment is most valuable sometimes essential but what counts far more is the aid of skilful and devoted men and women I was once involved in a medical emergency an *epidemic of poliomyelitis in which 2 000 children and* young people were stricken Excellent equipment was sent promptly and on a generous scale But the organization required to provide effective treatment was lacking Then five physiotherapists and one occupational therapist were brought in and within six months they quietly achieved a revolution that extended far beyond their immediate field of work After their efforts the surgical organization presented no difficulty

2) The most potent form of aid is teaching the teachers for it is on their continuing influence that the orderly evolution of a country's medical services ultimately depends It is not always convenient to find a place in a university medical department for a young lecturer or associate professor from abroad yet the good that can come from so

doing may be incalculable It is not only the acquisition of certain skills that counts the atmosphere of the place will influence him profoundly Whether in years to come his heart is in the advancement of medicine or in advancing himself may be determined by the example of those he has encountered in his impressionable years

3) Visit of longer or shorter duration by senior men to the developing countries can be valuable too In Great Britain we have before us an outstanding example in the late Julian Taylor who devoted the last years of his life to teaching surgery in Khartoum (A friend of mine is now taking his place) His influence was enormous for he identified himself completely with the Sudanese and was idolized by his students American surgeons are working some at their own expense on a shift system in countries as diverse as Jordan and India

4) For the broadening of a young man s mind a period of work in another country has long been regarded as desirable Years ago the British went to Germany to Vienna to Paris now the great magnet is the United States of America For the keen ambitious young clinician or scientist this is still almost essential To suggest that he should turn his thoughts to Asia or Africa is hardly realistic for there are few schools in these continents of any great distinction However there are some as several young Englishmen have discovered to their advantage

But we tend to forget that among our students there are a number who do not aspire to eminence who are not endowed with great originality yet are remarkable for their pioneering spirit and love of adventure They correspond to the missionaries and colonial officers of the last century to the men who were willing to face the great hazards (as they were then) of an unhealthy climate to forego the amenities of family life to forfeit whatever claim they might have had to public recognition for the satisfaction of creating something out of nothing and knowing that in one remote corner of the world they were indispendable Today conditions are far easier Yet the ardour of youth is still there and it is too precious to be wasted It is helpful if medical teachers and administrators can so order affairs that these young adventurers (they must be good at their job) can work for a time in countries where their help is welcome without losing their footing on the ladder at home This can be and is being done by a process of secondment so that the young clinician or student of preventive medicine is assured of a good place on his return A few by natural selection find their vocation abroad and then a service has been rendered

to a country short of well trained men The majority those who return bring back with them a poise and confidence borne of having shouldered great responsibilities under often irksome conditions

The scientific opportunities are considerable too If as is desirable arrangements have been made for the young man to devote a good deal of his time to a particular problem he will be able to collect his observations with a speed that cannot be approached in more sophisticated countries simply on account of the wealth of material His work will have a quickening influence on his new colleagues perhaps on his seniors and at the end he will have done something to advance medicine in a part of the world less favoured than his own

For ourselves there must be an awareness of these obligations a willingness perhaps at some sacrifice to meet them by giving the most practical encouragement to our colleagues senior and junior who feel drawn to participate directly in this pioneer work

SUMMARY

Although specialization in medicine depends on there being an adequate ratio of doctors to population it cannot be regarded as a luxury because the need for special medical or surgical services is greater in poor countries than in those in which medical care is highly developed In orthopaedics for example a number of crippling conditions which used to occupy the attention of surgeons such as poliomyelitis and joint tuberculosis have been largely eliminated in say Western Europe This has not yet come about in many parts of Asia and Africa The difficulty is that expenditure necessarily very limited must be devoted primarily to the promotion of public health the curative services important as they are must take second place

This essay contains suggestions on how help can be given where it is most needed

ZUSAMMENFASSUNG

Obwohl Spezialisierung in der Medizin davon abhangt dass eine hinreichende Anzahl von Ärzten im Verhältnis zur Bevolkerungsdichte vorhanden ist kann sie doch nicht als ein Luxus angesehen werden da das Bedurfnis fur medizinische und chirurgische Spezialhilfe in armen Landern grosser ist als in jenen in denen die medizinische Fursorge hoch entwickelt ist In der Orthopadie zum Beispiel sind

eine Anzahl von verkruppelnden Zustanden die den Chirurgen sehr beschaftigten wie Poliomyelitis und Gelenktuberkulose in Westeuropa sozusagen weitgehend ausgeschaltet worden Die Schwierigkeit ist dass die Ausgaben die notwendigerweise sehr begrenzt sind vor allem zur Forderung der offentlichen Gesundheit aufgewendet werden mussen während die Heilungsvorsorge so wichtig sie ist erst an zweiter Stelle steht

Der Aufsatz enthalt Bemerkungen uber die Moglichkeit dort Hilfe zu geben wo sie am meisten benotigt wird

RESUME

Bien que la specialisation en medecine depend du nombre des medecins qui existent par rapport a la population elle ne peut pas etre consideree comme un luxe car le besoin de specialistes en médecine et de services de chirurgie est plus eleve dans les pays pauvres que dans ceux ou le niveau des soins medicaux est hautement developpe C est ainsi qu en orthopedie certaines formes d invalidite qui retiennent generalement l attention des chirurgiens comme par exemple celles decoulant de la poliomyelite et de la tuberculose articulaire ont ete en grande partie eliminees en Europe occidentale La difficulte rencontree par la specialisation reside evidemment dans le fait que les fonds qui sont necessairement limites doivent etre utilises en premier lieu au progres de la sante publique et que les services de cure quelle que soit leur importance viennent au second rang

Cet essai montre comment l aide la plus necessaire peut etre apportée

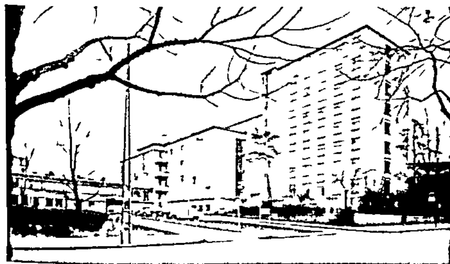
FROM THE TÖÖLÖ HOSPITAL AND FROM THE CLINIC FOR ORTHOPAEDICS AND TRAUMATOLOGY UNIVERSITY OF HELSINKI (HEAD PROF K E KALLIO)

ACCIDENT SERVICES IN A UNIVERSITY HOSPITAL

By

K F KALLIO

How to organize accident centres is probably one of the most urgent problems in the world of surgery and medicine today This article is intended to describe an accident hospital for musculoskeletal intra cranial and abdominal injuries for an area of about 800 000 of population *including the capital of Finland* *The hospital complex consist* of two parts as seen in the photographs



Th main building of the T lo H spital serves entirely for accidents and orth p edic surgery c ntaining nursing ards for 00 patients The operative department is n the upper flo r and con ists of f e theatres and one postanaesthetic nursing r m Different offices au lit r um f r 100 students and dining r oms are located in th econ l fl r central kitchen central heating s stem central l borator and r m f r medical student being l cated down in the first floor A wing large and quite new i attache l to the main building al ove

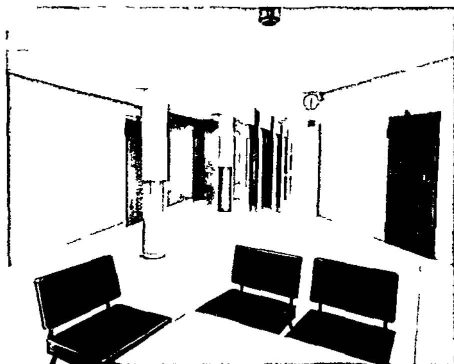


The wing seen here from the side of the casualty entrance is lower composed b three floors The upper third floor consists of the *Neurosurgical Clinic* with its wards and its operative department for four modern theatres and the *Central Automatic X ray Department* The whole second floor on the street level is constructed for *Casualty and Outpatient Departments* with opposite separate entrances for each The casualty entrance leads to the reception desk to the waiting and examination rooms to three shock rooms for major accidents and to two operation theatres for minor injuries There is a direct corridor connecting with the big ordinary Outpatient Department The separate entrance of the Outpatient Department leads via information and reception de k to the large main waiting room This again is openly connected with a number of examination instruction and dressing rooms This outpatient service has an operative department of its own, consisting of three modern theatres and a vast plaster room *The Central Blood Bank Service* with its laboratories the *Rehabilitation Department* including a pool facilities for physio and occupational therapy the *Central Supply Service Hospital Pharmacy* and *Electroencephalography* work in the first floor

THE HOSPITAL AS A WHOLE

The hospital directed by the present writer is called Toolo Hospital The number of regular beds is 255 out of which 80 are reserved for orthopaedics 61 for neurosurgery and the rest for accidents as mentioned above The turnover of the Toolo Hospital last year was 40 557 new cases of which 4 632 were in patients with 79 735 hospital days

During office hours the *Outpatient Department* is run in turn by a team consisting of two senior orthopaedists one neurosurgical and five orthopaedic registrars *Casualties* A seperate duty team takes care of casualties This team consists of one senior orthopaedist and one senior neurosurgeon together with three registrars One of the opera



Operati n theatres of the Outp tient Department

tion theatres of the outpatient department is used for nonaseptic clini cal cases The outpatients have to make an appointment for their visits and to have a written recommendation There are about 350 out patient visits a day The annual ambulatory turnover was 93 088 of which 22 321 were casualties *The Blood Bank System* of the Finnish Red Cross is fortunately located in this hospital open day and night A specialist in *Physical medicine and Rehabilitation* is responsible for the corresponding department the turnover of which last year was 36 821 visits All registrars of the hospital have to take care of the exercises of the in patients This so-called non stop exercise system is uniformly used throughout the wards

The X ray Department is run by two senior radiologists one registrar specializing in roentgenology of bone and joint and two rotating regi strars The automatic X ray machinery produces finished dry radio-graphs in 15 minutes Last year the production of X ray pictures was 95 882 – The newly constructed large *Central Laboratory* was opened

only at the end of 1961 Its chief is a lecturer in internal medicine specializing in laboratory work The service for *Electroencephalography* had last year 1 829 examinations of which 746 were for in patients – The hospital is divided into two university clinics

THE CLINIC FOR ORTHOPAEDICS AND TRAUMATOLOGY

This clinic has 194 beds of which 80 are reserved for orthopaedics. Its chief is the University Professor of Orthopaedics and Traumatology The staff consists of 5 lecturers who are senior orthopaedic surgeons with a complete schooling also in general surgery 15 registrars of which 5 are qualified general surgeons specializing for 2–3 years in orthopaedics and traumatology the other 10 are rotating registrars obtaining practice for general surgery in one year There are furthermore 10 so called amanuenses almost qualified physicians practising for 3–6 months The number of nurses is 81 of which 18 belong to the operation department of the clinic with five theatres and a postanaesthetic room The nurses of the clinic are helped by so called assistant nurses with a minor schooling numbering 53 About 3 000 operations were performed last year and the clinical material consisted a o of 1 400 fractures and furthermore of abdominal thoracic peripheral nerve and vascular injuries

The work of the clinic starts at 8 o clock in the X ray department attended by the whole staff whereafter some of the surgeons take care of the wards and the others of the operative work Each Wednesday the professor makes the rounds of half the clinic As regards the development of surgery one of the seniors takes care of surgery of the hand one of vascular surgery one of serious injuries of the spinal column and one of plastic problems Occasional difficult problems needing specific thoracic surgery are transported to the University Clinic for Thoracic Surgery The maxillary and mandibulary fractures are treated by a visiting oral surgeon from the University Dental Clinic Facial injuries needing plastic surgery are sent to the Red Cross Hospital for Plastic Surgery in the city As regards the aftercare and follow up patients are routinely treated twice a week partly by the outpatient department partly by a hospital team

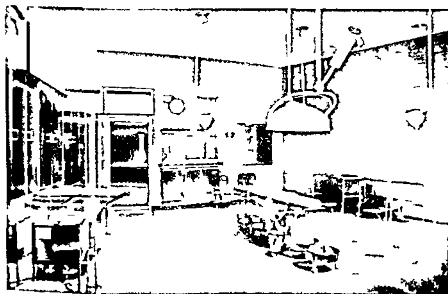
Teaching There are at present 60 medical students called candidates to be taught Lectures by the professor are given twice a week

and after these lectures the students divided into small groups are instructed by the senior surgeons A team of these students also attends the work of surgeons on duty — As regards the surgical instruction the whole staff attends each Saturday morning from 8 o clock until 11 o clock the staff conference and meeting of the clinic arranged by a lecturer and headed by the professor At this occasion also the programme for the following week is decided The activities of the hospital and the Saturday morning meetings in particular are apt to stimulate scientific thinking Research work is continuosly going on

THE CLINIC FOR NEUROSURGERY

This clinic has 61 beds This clinic headed by Dr Gunnar af Bjorkesten University Lecturer in Neurosurgery takes care of operative intracranial injuries 1 500 neurosurgical in patients were treated last year with 5 900 hospital days The number of operations was 752 The staff of this clinic consists of three senior neurosurgeons and four registrars There is continuous cooperation between the two clinics A chair of neurosurgery was established recently

Concluding I should say that this type of university hospital offers excellent opportunities for teaching training and resarch The com



One of th p ration theatre

bined duties and functions of traumatology orthopaedics and neurosurgery explain the fact that the hospital seems to be overstaffed compared to its complement of patients or beds To the staff belong a number of different specialists but it could not work successfully without general surgeons with modern knowledge and skill Due to the fact that only a qualified general surgeon in Finland is permitted to specialize in orthopaedics and that even most of the rotating registrars have had earlier experience in surgery the accident services in the Töölö Hospital have proved to be workable although more full time surgeons are desired An orthopaedic surgeon is most privileged working together with a neurosurgeon in the enthusiastic atmosphere of an accident hospital

SUMMARY

Toolo Hospital the accident centre of Helsinki directed by the writer containing the University Clinic for Orthopaedics and Traumatology and the Clinic for Neurosurgery is described The turnover of this hospital of 255 beds was last year 40 557 new cases of which 4 632 were in patients The outpatient department was visited by 93 688 patients of which 35 925 were new the number of casualties being 22 321 The number of staff members is 40 consisting of 28 surgeons 4 X ray men 5 anaesthetists and 3 other specialists The hospital has offered excellent opportunities for teaching training and research and it has also worked successfully in accident services Only a qualified general surgeon in Finland is permitted to specialize in orthopaedics

RESUME

Description de l hopital de Toolo qui est le centre d Helsinki pour les accidentes dirige par l auteur qui contient la Clinique de l Université pour l orthopédie et la traumatologie ainsi que la Clinique de Neurochirurgie Cet hopital qui compte 255 lits a traite l annee dernière 40 557 nouveaux cas dont 4 632 malades hospitalises Le Service des traitements ambulants a ete consulte par 93 688 malades dont 35 925 étaient des cas nouveaux le nombre des accidents s elevant a 22 321 L hopital a une equipe de 40 membres dont 28 chirurgiens 4 radiologistes 5 anesthesistes et 3 autres specialistes L hopital a fourni d excellentes conditions a l enseignement l entraînement et la recherche Il a eu aussi beaucoup de succes dans le traitement des accidentes Seul un chirurgien general qualifie est autorisé en Finlande a se specialiser dans l orthopédie

ZUSAMMENFASSUNG

Töölö Hospital, das zentrale Unfallskrankenhaus in Helsinki, das vom Verfasser geleitet und die Universitetsklinik für Orthopädie, Traumatologie und die Klinik für Neurochirurgie umfasst, wird beschrieben. Die Patientanzahl dieses Krankenhauses mit 255 Betten war im letzten Jahre 40 557 neue Fälle, von denen 4 632 in das Krankenhaus aufgenommen wurden. Das Ambulatorium wurde von 93 688 Patienten besucht, von denen 35 557 neu waren. Die Anzahl der Unfälle war 22 321. Die Zahl der Stabmitglieder ist 40 und besteht aus 28 Chirurgen, 4 Röntgenologen, 5 Narkotisoren und 3 anderen Spezialisten. Das Krankenhaus bietet ausgezeichnete Möglichkeiten für Unterricht, Ausbildung und Forschung, und es hat auch mit Erfolg in der Unfallshilfe gearbeitet. Nur ein in allgemeiner Chirurgie qualifizierter Arzt kann in Finnland sich in der Orthopädie spezialisieren.

A THEORY OF BONE FORMATION

By

J TRUETA

Over two hundred years of clinical observation and experimental research have failed to clarify the mechanism of bone formation despite the undeniable progress made in the study of many of the factors involved It has been the writer's privilege to be able to concentrate on the study of the vasculature of bone and on the part the vascular system plays in osteogenesis As a result of most of these works (*Trueta Trueta et al*) a concept of bone formation has progressively emerged which as new evidence has been collected has approached near conviction

In a few words the concept is that the wall cells of the bone capillaries and sinusoids – endothelial cells – are responsible for the formation of osteoblasts directly or by the intervention of one or more intermediate cells In the following pages are given some of the facts which may contribute to the understanding of the way in which the endothelial cell becomes a bone forming cell

The data in support of the osteogenetic properties of the bone vessels has been accumulated during the investigations of the vasculature of the callus of fractures and of the growth cartilage the incorporation of bone grafts and the osteoporosis following muscle inactivity We have concluded that the factors underlying the unexplained Wolff laws of trabeculae deposition and orientation (1870) are mediated by the particular positioning of the osteogenetic vessels (*Trueta* 1956b 1958 1960 1961b)

As reported elsewhere (*Trueta* 1958) the progression of the vessels is towards the ischaemic area at the centre of the fracture site (Fig 1) But what seems relevant here is that the deposition of new bone in the form of provisional trabeculae is also found in radiating form moulded onto the vascular patterns (Fig 2)

The following is a summary of the way in which we believe the ves



Fig I

Experimental fracture of the radius (rabbit) The perfussed vessels all point towards the ischaemic ends of the bone fragments and the mature cartilage The vascular stimulating factor (V S F) is produced here



Fig II

Radiating orientation of provisional trabeculae in the callus of an experimental fracture in the rabbit These trabeculae are exactly moulded into the vascular pattern

sels enter into osteogenetic activity The endothelial cells of the walls of the advancing vessels divide not only at their extending ends but along large sections of their wall and lay down a progeny of either osteoblasts or their near predecessors (*Trueta* 1961) All these cells from endothelium to osteocyte remain attached by intercellular cytoplasmic connections After the osteoblasts have laid down the collagen and polysaccharide matrix and have subsequently become buried by the deposition of apatite the cytoplasmic attachments to their ancestors prevent the deposit of mineral from becoming an isolating wall Canaliculae will thus appear round each of the cell expansions and the original syncytium will be preserved by the rigid mineral structure characteristic of bone

We have studied with the help of the electron microscope the suc



Fig 3

Ele tron microscope photograph Vessel of a Haversian canal full of erythrocytes cut longitudinally Its endothelium is becoming incorporated into bone × 3000

cessive stages by which these vascular cells become incorporated into bone and with the collaboration of Dr K Little we have been able to illustrate this point to our satisfaction The reason why we have been able to collect all this data on the vessel wall is because our sections including most of those for the electron microscope have been obtained from perfused specimens in which the vascular lumen remains patent (*Truela & Little* 1960) Our data of the area of active bone formation in the calcified tubes of the metaphysis during growth is abundant and *Rigal* (1961) in our laboratories has found by cell labelling with tritiated thymidine that many of the endothelial cells of the vessel wall enter the synthetic phase of their mitotic cycle i e are preparing to divide

Questions may be raised as to the validity of this concept of bone formation when applied to the origin of the haversian system of the osteones Consequently it was thought necessary to elucidate the role the vessels play in the organization of the haversian system of cortical bone

The data presented here was obtained by the use of the electron



Fig 4

Optic microphotograph One single row of osteoblasts separates the wall of the central vessel from the calcified canal The syncytium constituted by all these cells and the osteocytes round them is well seen × 700

microscope and particularly by microscopy under ultraviolet light following the injection of tetracycline and the subsequent perfusion of the animal – mainly the guinea pig or rat – with the 2 per cent solution of Berlin Blue

The part the periosteal vessels play in nourishing the outer layers of the cortex has been mentioned before we must point out that the vascularity of the periosteum is much greater during growth than after its cessation But in both young and adult the vessels of the periosteum appear as responsible for the origin of the osteoblasts as are those of the trabecular system

The deposition of subperiosteal bone is made like geological strata in successive layers each of which is vascular in origin On close examination of the single or double vessel of the Haversian canal after perfusion it appears frequently that the endothelial cell is in immediate connection with the osteoblasts either directly or by the intermediation of a single cell (Fig 3) With ultraviolet microscopy the tetracycline deposition – which indicates the area of previous labour of the osteoblasts – so perfectly corresponds with the outer perimeter of the vessel

that the only rational conclusion seems to be that both of them are very intimately related to each other

In the light of these findings one cannot but admire the perfect arrangement by which the transudates from the central vessel can reach the cells at the depth of the osteone Each row of osteocytes keeps its syncytial link by means of its cytoplasmic prolongation with the row it encircles until the more central line of osteocytes embraces and connects the osteoblasts and these the cells of the vascular wall (Fig 4) This material is now being prepared for publication with the collaboration of Dr Rios Leal

BONE REMOVAL

We have elsewhere referred to a mechanism of bone removal (*Geiser & Trueta* 1958) and have pointed out that the normal process of bone resorption in this experiment depended on vascular changes It seems unnecessary to mention that either reduced apposition of bone or its increased resorption can be produced by withdrawing from the blood some of the essentials required for bone formation such as O and vitamins A C and D calcium and phosphate salts



Fig 5

Electron microscope photograph Osteoclast with a number of its component cells seen still attached to the cells of the resorbing bone by cytoplasmic prolongations × 2500

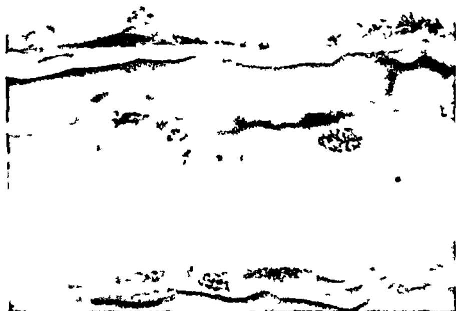


Fig 6
Endothelial vascular cells labelled by tritiated thymidine in the phase preceding cell division (tissue culture) × 800

We shall now discuss in the light of our findings the possible role of the osteoclasts as the agents of bone removal

We have been able to obtain microphotographs of osteocytes connected to neighbouring osteoclasts by cytoplasmic expansions of exactly the same nature as those linking osteocytes with each other or with the osteoblasts of their vicinity (*Trueta* 1958) No other explanation was found that the osteoclasts include osteocytes and nearby osteoblasts from the same area of syncytium and probably intermediate cells also In this *Tonna* (1960) and *Young* (1961) coincide and the evidence with tritiated thymidine obtained in our laboratory further supports the view that osteoclasts are formed by osteocytes osteoblasts and/or intermediate cells

In bone resorption caused by muscle inhibition (*Geiser* & *Trueta* 1958) the number of osteoclasts present is enormous This does not prove other than in this type of osteoporosis osteoclasts are formed in large number But are they the initiators of bone removal – as *Kolliker* (1873) thought they were – or are the osteoclasts a simple consequence of the resorption of bone as *Recklinghauser* (1891) preferred

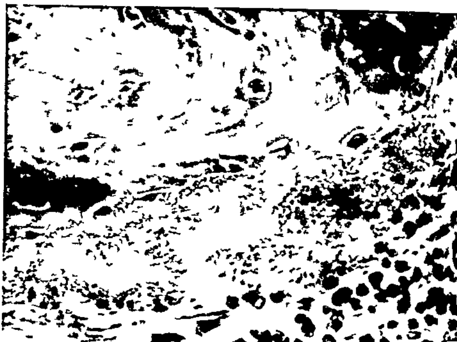


Fig 7

Perfussed vessel (Micropaque) demonstrating the active elaboration of bone by its endothelium × 600

to think? This is not an academic question for if it were possible to clear up this point the control of such a severe disability as clinical osteoporosis would be nearer

We have little doubt about this Dozens of works and papers on the origin of the osteoclasts by people who assign a specific nature to such cells had failed to discover from where they come and what causes them to appear Again no light had been thrown on the final destination of the bone cells and their syncytial connections which must be left to withstand conditions for which they were not prepared once the crystals of apatite have been washed away in the early stages of bone removal (Fig 5) In one point we may differ from the workers who doubted the agressive nature of the osteoclasts and denied any osteolytic power to them (Fig 6) It has been widely recognised that degenerating or dead osteocytes liberate some substance that is responsible for the removal of the mineral limiting the bone lacunae It may well be that the accumulation of defective osteocytes preserves in the osteoclast even perhaps enhances the agressive property of the osteocytes from which they are mainly formed But this does not detract

Thus from the conviction that what makes the osteoclast appear is the initial bone removal caused by the vascular mechanism to which we have referred *Kelly Little & Courts* (1959) have shown the part that an alteration of the matrix plays in causing osteoporosis

Many important aspects of the osteogenetic process remain still a mystery and thus are subjected to theorising and controversy Such is the case with this constant attendant at osteogenesis which is alkaline phosphatase But of one thing at least we are certain namely that bone is an organized soft tissue of which only part has been made rigid by the deposit of calcium salts The organiser is the osteogenetic vessel from which springs the syncytial frame of cells and their connections on which the bone architecture is established Endothelial cell – intermediate cell – osteoblast – osteocyte – osteoclast constitute the normal sequence of cellular philogeny in the constant elaboration and removal of the bone substance The initial cells on which the whole process rests are those of the capillary sinusoid vessel (Fig 7) which is responsible for providing the transudate on which the life and health of the whole syncytium depends

SUMMARY

A concept of bone formation based on the reproductive activity of the endothelial vascular cells of bone capillaries and sinusoids has been explained and some of the data on which this concept is based adduced An intimate connection amounting to cell continuity is postulated between the endothelial cell the intermediate cell the osteoblast the osteocyte and the final conglomeration of most of them in the cell we know as osteoclast

RESUME

Une conception de formation osseuse basee sur l activite reproductive des cellules vasculaires endotheliales des capillaires osseux et des sinusoides est expliquee et quelques unes des donnees sur lesquelles cette conception est basee sont fournies Il est pretendu qu il existe une étroite liaison en ce qui concerne la continuité des cellules entre la cellule endothéliale la cellule intermediaire l osteoblaste l osteocyte et la conglomération finale de la pulpart de ceux-ci dans la cellule que nous connaissons comme ostéoclaste

ZUSAMMENFASSUNG

Eine Auffassung der Knochenbildung, der die reproduzierende Tätigkeit von endothelialen Gefässzellen der Knochenkapillaren und Sinusen zu grund liegt, wurde erläutert und einige der Tatsachen auf denen diese Auffassung gegründet ist, wurden angeführt. Ein enger Zusammenhang, der einer Zellkontinuität zwischen den Endothelzellen, den intermediären Zellen, den Osteoblasten, den Osteozyten und der schliesslichen Verschmelzung der meisten von ihnen in die Zelle, die wir als Osteoklast kennen, gleichkommt, wird angenommen.

REFERENCES

Geiser, M. & Trueta, J. J. Bone and Joint Surg., *40 B*, 282, 1958.

Harrison, M. H. M., Schajowicz, F. & Trueta, J. J. Bone and Joint Surg., *35 B*, 598, 1953.

Kolliker, H. Die normale Resorption des Knochengewebes. Vogel, Leipzig, 1873.

Kelly, M., Little, K. & Courts, A. Lancet, *ii*, 1125, 1959.

Recklinghausen, F. D. von Festschrift f. R. Virchow, Berlin, 1891.

Rigal, W. M. A study of Bone Development using Tissue Culture as the Main Technique. D. Phil. Thesis, Oxford, 1961.

Tonna, E. A. Anat. Rec., *137*, 251, 1960.

Trueta, J., Barclay, A. E., Daniel, P. M., Franklin, K. J. & Pritchard, M. M. L. Studies of the Renal Circulation. Blackwell Scientific Publications, Oxford, 1947.

Trueta, J. Bull. Hosp. Joint Dis., *14*, 5, 1953.

Trueta, J. & Harrison, M.H.M. J. Bone and Joint Surg., *35 B*, 442, 1953.

Trueta, J. & Cavadias, A. X. J. Bone and Joint Surg., *37 B*, 492, 1955.

Trueta, J. Acta Med. Belgica, suppl. 1, 165, 1956a.

Trueta, J. Lancet, *i*, 585, 1956b.

Trueta, J. J. Bone and Joint Surg., *39 B*, 358, 1957.

Trueta, J. Rev. Chir. Orthop., *44*, 3, 1958.

Trueta, J. J. Bone and Joint Surg., *41 B*, 671, 1959.

Trueta, J. Nursing Mirror, 20 May, p. 5, 1960.

Trueta, J. & Morgan, J. D. J. Bone and Joint Surg., *42 B*, 97, 1960.

Trueta, J. & Little, K. J. Bone and Joint Surg., *42 B*, 367, 1960.

Trueta, J. & Amato, V. P. J. Bone and Joint Surg., *42 B*, 571, 1960.

Trueta, J. In press, 1961a.

Trueta, J. J. Trauma, *1*, 5, 1961b.

Wiley, A. M. & Trueta, J. J. Bone and Joint Surg., *41 B*, 796, 1959.

Wolff, J. Virchows Arch. f. path. Anat., *50*, 389, 1870.

Young, R. W. Autoradiographic Studies on Thymidine – H_3 Metabolism in Bones of Young Rats. Program Gordon Research Conference on the Chemistry, Physiology and Structure of Bones and Teeth, Meriden, New Hamshire, 1961.

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MORPHOLOGICAL STUDIES OF FRACTURE HEALING IN TISSUE CULTURE

By

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The tissue culture technique has been used for morphologic studies of fracture healing on rare occasions by earlier authors (*Niven* 1931, *Krull* 1936, *Weil* 1951, *Bucher* 1952) and then only the regenerative properties of embryonic bone have been studied. Tissue culture is, however, a method of experimental biology which seems advantageous for such studies. Contrary to studies *in vivo* the tissue culture technique allows the process of morphologic and biochemical differentiation of fracture healing to take place and develop in a simplified and well defined system, not influenced by local and general factors occurring in the experimental animal. Furthermore, the experimental conditions are more or less standardized during the healing process and can be modified at will.

The present communication is a report of an investigation undertaken to study the morphological process of regeneration of adult and embryonic bone in tissue culture. Furthermore, in a series of cultures an attempt has been made to influence the rate of the regenerative process by adding RNA to the culture medium. RNA has been reported (*Emanuelsson* 1960) to possess differentiation promoting biological properties.

METHODS AND MATERIALS

The watch-glass tissue culture method of *Fell & Robison* (1929) was used throughout. A solid medium was used in all the cases and it was composed of ... plasma and freshly prepared tissue extract derived from 12 day old chick embryos. The plasma and tissue extract were suspended in 1% glucose enriched Tyrode solution in a proportion 12:1:3 respectively. The cultures were transferred to fresh medium 3 times a week and were incubated at 37° C.[1]

[1] For details regarding the tissue culture technique the reader is referred to a previous work by the author (1955).

In one group of cultures a small amount (3 drops) of a 0.26 mg/ml solution of yeast RNA was added to the medium

The cultures were derived either from adult roosters or from chick embryos. Cultures from adult bone were prepared as follows. The ribs of young roosters were dissected free from adherent soft tissues and the majority of the periosteal membrane. Then they were divided by vertical sections in small pieces of about 2 mm of length. Each piece of bone was further divided by transversal section into two bits. The bone fragments were first bathed for some minutes in a Tyrode's solution to remove small soft tissue particles, then the endosteal surfaces were pressed gently together and the adherent fragments were finally explanted to the previously prepared culture medium

Embryonic bones were obtained from chick embryos at the 18th day of incubation. The ribs were also used in this case. They were dissected in a similar way and were divided in 3–5 mm long pieces. Each piece of bone was then bent with force so that the cortical bone was broken on one side. In this way a "green stick" type of fracture was produced. Explantation on the culture medium followed after rinsing the bone pieces for a few minutes in a bath of Tyrode's solution

Preparation of the cultures was always performed under strict conditions of sterility. No antibiotics were added to the medium

The migratory activity of fibroblastic cells was studied in all cases and recorded according to the same principles followed in an earlier investigation (*Sevastikoglou* 1958)

Cultures were selected for sectioning every 5th day up to the [illegible]0th day of cultivation. They were fixed in a 10 per cent neutral formaldehyde solution and later decalcified for a short time with hydrochloric acid. The specimens were sectioned serially at 5 μ thickness and haematoxylin eosin and Azan stains were used

Altogether 158 cultures were studied and they were divided into the following groups: a) 20 cultures derived from adult bones, b) 100 cultures derived from embryonic bones and c) 38 cultures derived from embryonic bones and grown in a medium containing RNA

RESULTS

68 cultures in groups *b* and *c* were destroyed by infection or accident. No casualties occured in group *a*. The total of the remaining 90 cultures of all the groups were sectioned for histological studies. However in one culture of group *a* and in seven of group *b* and *c* no signs of fracture could be found in the serial sections, probably because of sectioning in a wrong direction. Furthermore 33 out of the 70 sectioned cultures of embryonic bone were destroyed by wrinkling and breaking of the specimens so that no details for comparative studies could be recorded in these cases. Thus only 19 cultures of group *a*, 21 of group *b* and 9 of group *c* were available for the histological study. Table 1 demonstrates the distribution of the material

Migratory activity of the cells appeared very early in the cultures of group *a*. Already during the first subcultivation—3rd day—there were

clear signs of radial migration of cells from the greater parts of the surface of 15 out of 20 cultures of this group. At the end of the 3rd week a thick halo of migrating cells was present in all the cases.

TABLE 1
Distribution of the Material and Results

Culture group	No of cultures	No of studied cultures	Formation of periosteal capsule	Presence of osteoid tissue
a	20	19	18 (94.6%)	10 (55.5%)
b	100	21	10 (47.5%)	7 (70.0%)
c	38	9	6 (66.6%)	0

Cultures of group *b* and *c* displayed a poorer activity of migrating cells than those of group *a*. In none of them was a real halo of migrating cells present throughout the period of cultivation. In 90 out of the total of 138 cultures of both groups no migratory activity of cells could be registered during the period of cultivation. In the remaining cases only radial migration from a limited area of the periphery of the cultures and in very few cases from the greater parts of their periphery could be registered.

Histological studies on cultures from adult bone. In histological sections the specimens are composed by two pieces of mature bone placed on each other. Compact bone is identified on the outer surface of the fragment and cancellous bone on their sides fronting each other. An interspace exists between the fragments in which small pieces of broken bone trabeculae are often found.

In the specimens grown in tissue culture for 5 days the bone fragments are composed in their greater part by living bone but small areas of devitalized bone were recognized in some places. A thin layer of fibrous capsule was visible on the superficial surfaces of the fragments. Numerous migrating fibroblasts were found within the interspace between the bone fragments. These cells formed a thin network, the appearance of which remained unchanged throughout the time of cultivation.

By increasing the time of cultivation the areas of devitalized bone increased and at about the end of the 2nd week both fragments were often found almost entirely devitalized.

The formation of the fibrous layer soon increased and both fragments were encased in a well developed capsule in all specimens after about 10 days of cultivation. At this stage the fibrous capsule had a

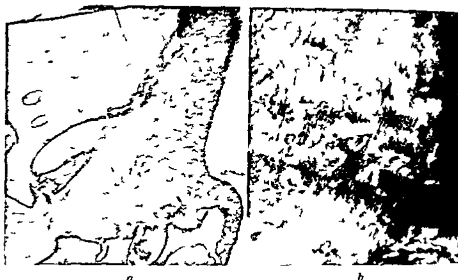


Fig 1

Adult bone culture in tissue culture for 59 days

a The two bone fragments are connected by the fibrous capsule Osteoid tissue arising from the inner layer of the capsule fills the one end of the fracture interspace and fuses the fragments The bone has devitalized appearance Haematox eosin × 65

b The osteoid tissue under high magnification Azan × 650



Fig 2

Adult bone culture grown in tissue culture for 18 days Osteoid tissue laid down by the periosteum Azan × 260

typical morphologic character of the periosteum with an inner osteoblastic and an outer fibrous layer

After about the 10th day of cultivation osteoid tissue usually appeared



Fig 3
Embryonic bone culture grown in tissue culture for 10 days The fractured embryonic trabecula is composed by living bone The periosteal capsule is visible at the top A network of migrating fibroblasts (down right) and part of the cartilage cone (down left) fill the medullar cavity Haematoxylin eosin × 260

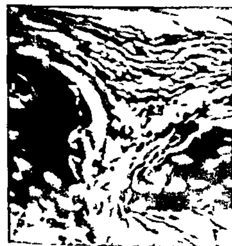


Fig 4
Embryonic bone culture grown in tissue culture for 20 days Migrating cells arising from the periosteal capsule fill the fracture space Azan × 260

at the ends of the interspace The osteoid tissue originated from the osteoblastic layer of the periosteal membrane and tended to fuse the bone fragments at their ends (Fig 1) In a few cases some osteoid tissue was laid down under the periosteum on the superficial surfaces of the fragments (Fig 2)

In 10 out of the 18 specimens in this group which developed a periosteal capsule osteoid tissue could be recognized in one or both poles of the interspace

Histological studies on cultures from embryonic bone The sectioned cultures both in group *b* and *c* were in all the cases composed of healthy



Fig. 5
Embryonic bone culture grown in tissue culture for 15 days. Osteoid tissue arising from the periosteal capsule (upper) fills the fracture space. Azan. × 260.

embryonic bone trabeculae. No signs of devitalization of the bone were observed in these cultures even after growth in tissue culture for longer periods up to 70 days. The medullary cavity was found in the majority of the specimens to include marrow elements and some migrating fibroblasts. In some cases, however, it was filled by hypertrophic and degenerated chondrocytes of the cartilaginous cone, while resting flattened chondrocytes were not present in any specimens (Fig. 3).

As the fracture was produced by bending the bone, the specimens of these groups had a special appearance. A rupture of the continuity of the periosteal bone, usually composed by a single embryonic bone trabecula, was seen in the convexity. A slight diastasis between the fragments of the trabecula was often present. A compression and breaking of the trabecula without dislocation was usually present in the concavity. In some cases the trabecula in this side was bent but not broken. This characteristic appearance could not, however, be identified in all the specimens, probably because of sectioning through different planes.

A fibrous layer began to form very early in the culture of these groups and it was appreciably thicker at the site of the concavity. In a great number of the studied specimens a well developed capsule was present after 5 to 10 days of cultivation. The fibrous capsule had the characters of periosteum and the inner osteoblastic layer had already differentiated at this stage. Migrating fibroblasts were often seen within the fracture space (Fig. 4).

Osteoid tissue also appeared at early stages of cultivation as a very

thin layer localized under the periosteum in the convexity of the specimen near the fracture At later stages of cultivation the fractured trabecula was bridged over by osteoid tissue which in some cases filled the fracture space (Fig 5) There were no signs of activity of the endosteal elements the appearance of the medullary cavity remaining unchanged throughout the period of cultivation

As a whole the number of sectioned cultures of group *b* which developed a periosteal capsule was rather low Thus in only 10 out of 21 of the specimens in this group could a well developed capsule be recognized The respective figure for cultures of group *c* was 6 out of 9 studied specimens Osteoid tissue was found to exist in 7 out of 10 specimens of group *b* in which a capsule had developed In the 6 cultures of group *c* in which formation of a periosteal layer was present no signs of osteoid tissue could be identified in the serial histological sections Both the formation of periosteal capsule and the development of osteoid tissue appeared in these groups as early as the 5th day of cultivation These activities were however appreciably rarer in specimens of later age of cultivation

DISCUSSION

The results reported above demonstrate that there are several differences in the behavior of the cultures in the various experimental groups Likewise there are differences between the cultures of the various experimental series in the development of the process of fracture healing during growth in tissue culture

Contrary to cultures of group *b* and *c* those belonging to group *a* displayed an early and intense activity of migrating cells Migrating cells probably originated from periosteal remnants which had remained adherent on the surface of the bone fragments despite careful dissection Fibrocytes of the periosteal remains migrate into the medium as fibroblasts and by proliferation form a fibrous capsule covering the culture The capsule soon differentiates into a fibrous and an osteoblastic layer and a new periosteum is thus formed As periosteum is more adherent to adult bone it can be assumed that cultures of embryonic bone had less periosteal remnants and therefore they displayed a poorer migratory cell activity On the other hand it is also possible that the very thin embryonic bone used in group *b* and *c* was exposed under dissection to comparatively larger mechanical injury than the adult bone used in group *a* An impairment of the regenerative capacity of the embryonic bone can therefore be suspected

The periosteal capsule was formed in a parallel way with the migratory activity of the cell. Cultures of group *a* which showed early and intense migratory cell activity developed a capsule very soon and in a higher percentage than cultures of group *b* and *c*.

Once the periosteal capsule had developed the process of healing began in the cultures and resulted in the formation of osteoid tissue of periosteal origin. A relationship between the development of the periosteal capsule and the production of osteoid tissue is supported by the fact that no osteoid tissue could be found in specimens which did not develop a periosteal capsule. The frequency of periosteal capsule formation in the three groups was 94.6 % of the cultures in group *a*, [illegible] in group *b* and 66.6 % in group *c*. The frequency of osteoid formation in the cultures showing a periosteal capsule was highest in group *b* (70 %) followed by group *a* (55.5 %). No osteoid tissue was seen in any of the sectioned specimens in group *c*, thus there was no evidence of osteogenic healing properties in this group. (See table 1)

The number of the studied cultures in the three groups is too small to allow definite conclusions. Furthermore the comparative value of the results described is reduced because the material used and the type of injury applied were different in the cultures of the various groups. However, the differences of the results reported here may indicate that although cultures of adult bone show an intense activity of migrating cells and form a well developed periosteal capsule in a high percentage, cultures derived from embryonic bone and grown under identical experimental conditions (group *b*) show a stronger regenerative activity and form osteoid tissue more frequently. This fact must be attributed to a greater regenerative power in cultures of embryonic bone.

Cultures derived from embryonic bone but grown in a medium containing yeast—RNA failed to display development of osteoid tissue in spite of a high incidence of periosteal capsule formation. This is remarkable in view of the observation reported above that a relationship exists between capsule formation and osteoid tissue production. Apparently capsule formation is a requisite for the production of osteoid tissue but the capsule may or may not do so. It seems that a well developed periosteal capsule can be inhibited from producing osteoid tissue.

Another difference between cultures of group *a* and these of group *b* and *c* was the observation that extensive areas of the bone in group *a* suffered devitalization already during the early stages of cultivation. Cultures of the latter groups were composed exclusively by vital bone even at the latest stages of cultivation. The reason for this difference

is probably the different size of the cultures in the two groups Cultures of adult bone were considerably larger than these of embryonic bone The conditions for nutrition in tissue culture of small bone fragments in group *b* and *c* were much more favourable than for the large fragments in group *a*

By adding RNA in culture medium in group *c* the intention was to promote the rate of the regenerative process of the cultures However under the prevailing experimental conditions the RNA had an inhibitory rather than promoting effect on the fracture healing activity of the cultures but no generalized conclusions should be drawn from the reported results regarding the action of RNA on the regenerative properties of the cultures It has been proved that pure RNA in itself has the capacity of stimulating growth and differentiation in early chick embryos growing in tissue culture the effect being dependent however on the origin of the RNA used (*Emanuelsson* 1960) The RNA used in the present experiments was probably a denaturated unpure product neither organ specific nor homologous Weil (1951) found that heterologous Ossopan i e powdered whole bones added to the culture medium showed a clear promoting effect on the healing rate of fractured chicken embryonic bones grown in tissue culture Her results may be attributed to the existence of heterologous organ specific RNA in the used preparation

The healing process in the studied specimens of group *a* and *b* was restricted to the formation of osteoid tissue It has been stated earlier that formation of mature architecturally recognizable bone cannot be obtained in tissue culture (*Amprino* 1956 *Sevastikoglou* 1958) On the other hand in short termed experiments of fracture repair in tissue culture healing by formation of mature bone has been reported when embryonic bone of early stages of incubation 5 to 16 days was used (*Nw n* 1931 *Krull* 1936 *Weil* 1951 and *Bucher* 1952) Since the material and methods used by these authors were almost identical to those used in the present study an explanation for the discrepancy in the results could be the age of the embryonic bone used Perhaps the regenerative capacity of the embryonic bone varies considerably during the different stages of embryonic development and experimental investigation of this possibility is required

The described results suggest that under the prevailing experimental conditions the process of bone regeneration of the adult as well as the embryonic bone can develop in tissue culture in the absence of periosteum nerves and vessels and independently of central healing mechan

isms. The process is however limited to the formation of osteoid tissue and it therefore might be assumed that the final phase of bone regeneration in tissue culture is dependent on local or general mechanisms which act *in vivo* but are not available in tissue culture.

SUMMARY

Experimental fractures in adult and embryonic bone displayed a regenerative activity in tissue culture. Under the prevailing experimental conditions the healing process was limited to the development of a periosteal capsule and the formation of osteoid tissue of periosteal origin. The process developed in spite of the lack of nerve and vessel supply to the bone fragments and without the influence of other local or systemic mechanisms occuring in the living organism.

Fractures produced in embryonic bone showed a higher incidence of osteoid tissue formation. Adult bone cultures developed a periosteal capsule earlier and more frequently. No osteoid tissue was observed in cultures which did not develop a periosteal capsule.

The regenerative activity of the cultures was displayed by the formation of osteoid tissue of periosteal origin. The bone fragments showed no active participation in the healing process.

The addition of non specific RNA to the nutrient medium had an inhibitory effect on the differentiation of the periosteal capsule and the formation of osteoid tissue.

The important technical assistance of Mrs. *M. Lundblad Maunsbach* is acknowledged with great appreciation. The present study has been supported financially by Swedish Medical Research Council.

RÉSUMÉ

Les fractures expérimentales chez les adultes et dans les os embryonnaires manifestent une activité regénérative dans les cultures de tissu. Dans les conditions expérimentales du moment le processus a été limité au développement d'une capsule périostale et à la formation de tissu ostéoide d'origine périostale. Le processus se développe malgré l'absence de nerfs et de vaisseaux pour approvisionner le fragment osseux et sans l'influence d'autres mécanismes locaux ou systémiques apparaissant dans l'organisme vivant.

On a pu constater que la formation du tissu ostéoide était plus fréquente lorsqu'il s'agissait d'une fracture d'un os embryonnaire. Dans

les cultures d'os adulte il se développe plus tôt et plus fréquemment une capsule périostale. Aucun tissu ostéoïde n'a été observé dans les cultures où il ne s'est pas formé de capsule périostale. L'activité régénérative de la culture s'est manifestée par la formation de tissu ostéoïde d'origine périostale. Il n'est pas arrivé que les fragments d'os aient une participation active au processus de la guérison.

L'addition de RNA non spécifique au milieu nutritif a un effet inhibitif sur la différenciation de la capsule périostale et la formation de tissu ostéoïde.

ZUSAMMENFASSUNG

Experimentelle Brüche von Erwachsenem- und Embryoknochen zeigten eine regenerative Aktivität in Gewebskulturen. Unter den vorherrschenden Versuchsbedingungen war der Heilungsprozess auf die Entwicklung einer periostalen Kapsel und der Bildung von osteoidem Gewebe periostalen Ursprungs begrenzt. Der Prozess entwickelte sich trotz des Fehlens einer Nerven- und Gefässversorgung zum Knochenfragment und ohne den Einfluss anderer lokaler oder Systemmechanismen, die im lebenden Organismus vorhanden sind.

Brüche, die an Embryoknochen hervorgerufen wurden, zeigten ein häufigeres Vorkommen von osteoider Gewebsbildung. Gewebskulturen von Erwachsenen entwickelten eine periostale Kapsel frühzeitiger und häufiger.

Die regenerative Aktivität der Kulturen wurde durch die Bildung von osteoidem Gewebe periostalen Ursprungs aufgezeigt. Die Knochenfragmente wiesen keine aktive Teilnahme am Heilungsprozess auf.

Die Hinzufügung von unspezifischem RNA zu dem Ernährungsmedium hatte eine hemmende Wirkung auf die Differenzierung der periostalen Kapsel und die Bildung von osteoidem Gewebe.

REFERENCES

Amprino R In Ciba Foundation Symposium on Structure and Metabolism J & A Churchill Ltd London 1956

Bucher O Acta Anatomica Basel 14 98 1952

Emanuelsson H Acta Physiol Scandin v 48 3 ? 1960

Fell H B & Robison R Biochem Jour 23 767 1929

Krull C Arch orthop Unfallchir 37 131 1936 37

Niven J S F Jour Path Bact 35 307 1931

Stratikoglou J Acta Orthop Scandin v Suppl 33 1958

Weil I T Schweiz Z chr allg Path 14 20 1951

GROWTH OF THE EPIPHYSES AND VERTEBRAE

By

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In this hospital we have seen 3 patients whose histories and radiological investigations may throw light on some of the problems of ossification and bone growth. We found an unusual double contour in the epiphyses of the long bones of these patients. Similar phenomena were observed in the vertebral bodies of one of them.

Patient no. 1 (9553/45) was a woman who at the age of 5 contracted a left sided pulmonary abscess and underwent costal resection. The lung condition was quickly cured by this method. A slight scoliosis is all that is left from this incident; otherwise she has been in perfect health ever since. X-ray examination at the age of 26 (fig. 1a, 1b) shows in each of her vertebral bodies a well defined area of increased density of bone. These lines are placed centrally in the vertebral bodies except posteriorly where they almost reach the cortex of vertebral body. These lines are such in shape and size that they could well correspond to the vertebral bodies found at the age of 5. Similar lines were also found in the long bones of the extremities, best seen in the femoral and tibial epiphyses of the knee joint (fig. 1c, 1d).

Patient no. 2 (17239/56) was a man who at the age of 7 received a severe trauma resulting in multiple lesions (i.e. severe contusion of the left inguinal region, comminuted fractura of the left femur and total severance of the left sciatic nerve). The femoral fractura was treated first by osteosynthesis a.m. Lane, later by intramedullary nailing. This procedure was then complicated by the appearance of osteomyelitis and pseudarthrosis. The latter healed after 1½ years but the infection took 3 years to eradicate. The sciatic paralysis proved to be permanent. 4½ years following the injury an epiphysiodesis a.m. Phemister was performed in the right knee region. X-ray pictures of the left knee, taken 3 months after the traumatic incident (fig. 2a), exhibited a severe diffuse osteoporosis of the epiphyses and a zone of rarefaction between the metaphysis and the epiphyseal line with an uneven garland-like surface towards the epiphysis. The X-ray pictures of the lower extremities 6 years later (figs. 2b, 2c) display a similar central osteoporotic area in all of the epiphyses of long bones, but most markedly on the left side. It is surrounded by bone of normal structure but seperated from it by a cage of bone of increased density. Here again the whole central conformation could well correspond to the epiphysis of a 7 years old boy. We also found lines of thick bone in the diaphyses



Fig 11

f f m ra an l tibiae l e t cen in th left tibial the e lines the bone tructure e me l to l e n e l ne v a marke lly r ft

Patient no 3 (16199 4 va a f male 2 yea wa diagnose l in her left hip Thi e nditi n wa ti n te tom an l a etabul pla t Neverth l wa n t maintaine l su c full an l at the 5 perati ns on it Tw f the e were maj r talisation she contra ted chickenpox had rea



Fig 1c



Fig 1d

fered from minor wound infection An X ray examination of the knees at the age of 10 demonstrated centrally placed osteoporosis in the epiphyses this pathological change being most marked on the left side (fig 3) The structure of bone peripheral to this lesion is apparently normal Here again there is an intervening dense zone between the two

DISCUSSION

The most thorough study of lines of increased density in the shaft of long bones seems to have been undertaken by *Eliot et al* (19[illegible]) who found that these lines consisted of slices of bone in which the trabeculae were thicker and more transversely arranged than normal These trabeculae model themselves quite accurately to the provisional bone in which they are laid Though they may undergo resorbtion later they will never change their form Lines of arrested growth may develop in the metaphyses of any of the long bones when some pathological condition reduces temporarily the intensity of growth (e g in infectious diseases or quite banal diseases even after a small trauma)



Fig 3 i

In our experience there is considerable individual variation in the tendency to form such lines. As a rule, the more severe the trauma is, the thicker the line is likely to be, especially in the fastest growing epiphyseal zones.

Growth and ossification of the epiphyses have been investigated among others by *Eliot et al.* (1927), *Harris* (1929), *Siegling* (1941) and *Lacroix* (1952). It is generally agreed that epiphyseal growth occurs by enchondral appositional ossification spreading from an ossification center. In the first years of life this spread occurs centrifugally; later, however, it ceases on the surface facing the epiphyseal plate but continues in the other directions. This state of affairs is illustrated on our pictures 1c, 1d, 2b, 2c and 3.

Central epiphyseal osteoporosis similar to figs. 2b, 2c, 3 has been described by *Siegling* (1941) by administration of phosphorised cod liver oil and by *Goff* (1960) who observed the same phenomena in a case of poliomyelitis. A well defined diaphyseal osteoporosis, as illustrated on fig. 2c, has been seen by *Harris* (1929) whose case was a stillborn child with congenital lues.



Fig. 2b

Neither of these authors try to explain why, even after many years, these porotic areas persist, and why the texture of bone surrounding these lesions is normal.

The above described phenomena seem to be quite rare. Over a 10 year period at the Orthopaedic Hospital in Copenhagen, we have investigated the growth disturbances of 890 children using orthoradiographic methods. Apart from the 2 above reported cases we were unable to find similar abnormities in the rest of the children, although the majority of those examined had suffered from a variety of infectious diseases or received severe traumata.

It is not possible, from our 2 cases, to draw a satisfactory explanation for the persistence of osteoporotic areas so long after the trauma. For at least 3 years previous to the orthoradiographic examinations both children were in perfect health, and in the post traumatic developed bone the ossification took place apparently normally. These two facts lead us to think it very improbable that we were dealing with some lasting systematic illness. Further, since the peculiar phenomena



Fig. c

existed on the healthy side as well, the resulting pathological changes could not be exclusively due to local causes, e.g. vascular disturbances, inactivity or denervation. A possible explanation may be that the central osteoporotic areas are in fact a kind of sequestra encapsulated by sclerotic bone boxes that may well hinder normal revascularisation of their captive sequestra.

Concerning similar changes in the vertebral bodies (figs. 1a, 1b) we found only *Harris's* reference (1929) to the above mentioned stillborn and *Siegling's* (1941) who concluded from his findings that the growth of the vertebral bodies is faster in the anterior than in the posterior direction.

In our case we found that between the age of 5 and the conclusion of growth no enlargement appeared to have taken place in the posterior part of vertebral bodies.

Growth process in the vertebral bodies is considered to be analogous with the longitudinal growth of the diaphyses of the long bones (*Schmorl* (1939), *Haas* (1939), *Bick & Copel* (1950), *Roaf* (1960)). They regard the cartilage caps of vertebral bodies as true epiphyseal plates. The treatment of scoliosis by corporal epiphysiodesis, *Roaf's*



Fig. 3

technique is based on this assumption. *Bich & Copel* support the above theory with the observation that the texture of cartilage in the vertebral caps closely resembles that of the epiphyseal plates of long bones.

This morphology cannot be said to be exclusive to these two places because *Siegling* demonstrated that similar morphology could be found in the central part of the cartilage covering the epiphyseal nuclei. *Lütken* (1947) classified epiphyses and diaphyses according to their surface structure. In his opinion the ends of the vertebral bodies correspond to the epiphyses, and the intermediate cylindrical part of the vertebra is analogous with the diaphyses of long bones.

The formation of the strange box shaped zones of dense bone (figs. 1a, 1b) is somewhat difficult to explain by the described theory.

If it were correct, one would expect to find only horizontal lines in the vertebral bodies and no vertical ones. (According to the theories advanced so far, subperiosteal ossification in long bones cannot be inculpated for the genesis of vertical lines.)

Our findings indicate that growth of vertebral bodies takes place according to the fashion of endochondral appositional ossification and is quite analogous with the growth of epiphyses of long bones.

SUMMARY

3 cases are reported where a severe disease in childhood resulted in temporary halting of bone growth. The lines of increased density found in the epiphyses of long bones and vertebral bodies may indicate that growth in the vertebral bodies occurs in the same manner as growth of the epiphyses of long bones, namely by endochondral appositional ossification.

RÉSUMÉ

Il est référé trois cas de maladie grave de l'enfance qui a occasionné un arrêt temporaire de la croissance des os. Les lignes de condensation dans les épiphyses et les corps des vertèbres paraissent indiquer que la croissance du corps vertébral se fait d'une manière analogue à celle de l'épiphyse, à savoir comme une ossification endochondrale appositionnelle.

ZUSAMMENFASSUNG

Man berichtet über drei Fälle einer schweren Erkrankung im Kindesalter, die zu einem zeitweisen Stillstand des Knochenwachstums führte. Die auftretenden Kondensierungslinien in Epiphysen und corpora vertebrae konnten darauf hindeuten, dass das Wachstum in den Wirbelkörpern in analoger Weise vor sich geht wie in den Epiphysen, nämlich als eine *enchondrale appositionelle Ossifikation*.

REFERENCES

Bick, F. M. & Copel, J. W. Longitudinal Growth of the Human Vertebra. J. Bone & Joint Surg. 32 A 803 1950.

Eliot, M. M., Souther, S. P. & Park, E. A. Transverse Lines in X-ray Plates of the Long Bone in Children. Bull. John Hopkins Hospital. *41* 364 1927.

Gill, G. W. Surgical Treatment of Unequal Extremities. Charles C. Thomas, Springfield, Illinois 1960.

Haas, S. L. Growth in Length of the Vertebrae. Arch. Surg. 38 245 1939.

Harris, H. A. The Growth of the Long Bones in Foetal Life. Journal of Anatomy 63 3 1929.

Lacroix, P. The Organization of Bones. London, J. & A. Churchill 1951.

Lauritzen, P. Bruskskelet og epifyseproblem (With english summary) Disp. Ejnar Munksgaard, København 1947.

Roaf, R. Vertebral Growth and its Mechanical Control. J. Bone & J. Surg. 42 B 40 1960.

Schmorl, G. Zur Kenntnis der Wirbelkörperepiphyse und der an ihr vorkommende Verletzungen. Arch. f. klin. Chir. *153* 35 1928.

Stirling, J. A. Growth of the Epiphyses. J. Bone & Joint Surg. 23 23 1941.

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SIGNIFICANCE OF EXPERIMENTAL TERATOGENESIS IN ORTHOPAEDIC SURGERY

By

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During the nineteenth century a new line of research was conducted by great pioneers such as Saint Hilaire, Liharzik, Valentin, Gerlach, Lombardini and Dareste to establish on a scientific basis the department of experimental pathology known as "teratogenesis or the artificial production of malformations and monstrosities". A detailed review of the work done on experimental teratogenesis by various researchers has been given by the author in one of his previous articles (*Duraiswami* 1952). The author became interested in experimental teratogenesis as a result of an accidental observation he had made in 1943 while investigating the role of glycogen granules in hypertrophic cartilage cells in chick embryos during endochondral ossification (*Harris* 1932). In the course of his first series of experiments he injected five units of insulin into hens' eggs at various intervals after the beginning of incubation and to his pleasant surprise he noticed that some of the chicks showed radiographic appearances resembling osteogenesis imperfecta in the human. Some of them had shown abnormalities such as spina bifida, partial or complete suppression of the segment of one or more vertebrae, while others showed various deformities in the limbs. Since then a variety of congenital defects have been produced with sulphonamide compounds, thallium salts, cortisone, 3 acetylpyridine, lead salts, benzyl alcohol, isonicotinic acid hydrazide and certain antibiotics such as synnematin, terramycin and cycloserine (*Duraiswami* 1952, 1954, 1955, 1959, 1961).

MATERIAL AND METHODS

The experiments were conducted with eggs from white leghorn, New Hampshire red and Rhode Island Red chickens which were known to be free from gross



Fig 1

Radiograph of a path logical fracture of the left tibia in a 5-m nth old chicken with insulin induced osteogenesis imperfecta (resembling "postnatal" type The left first metatarsal sh ws mal united pathological fracture which preceded the tibial fracture by about two months Right tibia and right first metatarsal f r comparis n.



F 2

Twenty-day-old embryo sh wing ery h rt limbs (mic meli ndu d by insulin Normal tw nt -da -ld embry n th right f r comparison

Fig 3
Eighteen day old embryo showing defects of the limbs feet and beak induced by iso nicotinic acid hydrazide Normal eighteen day old embryo on the left

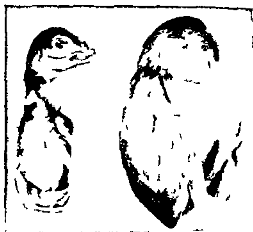




Fig 4
Twenty day old embryo showi limb and feet deformities i duced by synermycin (Plate Normal twenty-day-old embr on the right

abnormalities as well as nutritional deficiencies The methods employed f r i cubation of the eggs and for conducting histological and ra liological investi a n on chick embryos have been described previously (*Duraiswami* 1950 1957) S m of the defects induced by various teratogenic substances have been illustrated in Figures 1 to 4

DISCUSSION

In his previous publications (*Duraiswami* 1950 1952) the author furnished experimental evidence to prove that mechanical trauma of injection was not a factor in causing specific deformities induced by each teratogenic substance depending on its dose and the time at which it is injected into the egg after the beginning of its incubation It was also demonstrated (*Duraiswami* 1955) that teratogenic substances such as insulin cortone acetate 3 acetylpyridine and lead nitrate can induce

different types of malformations though the technique and time of injection and the method of incubation of eggs are for alle practical purposes the same On the other hand a limb deformity like the angulation of the tibia leading to pseudarthrosis can be induced in chick embryos by substances with different chemical compositions such as insulin sulphonamide compounds thallium nitrate benzyl alcohol iso nicotinic acid hydrazide and antibiotics like synermycin terramycin and cycloserine It does not necessarily follow that all these substances act in an unspecific manner in causing angulation of the tibia As a matter of fact the experimental evidence at our disposal points to the contrary

In the case of insulin it has been observed that hypoglycaemia and profound disturbance to the mucopolysaccharide metabolism may play a part in the causation of the appropriate deformity On the other hand sulphonamide compounds seem to induce the defect without lowering the blood sugar of the treated embryos However nicotinamide can prevent to a remarkable extent the defects induced by both insulin and sulphonamide compounds It has been shown by various workers that the developing chick embryos depend entirely on *de novo* formation of nicotinic acid nicotinamide and phosphopyridine nucleotides There is adequate experimental evidence to demonstrate that compounds which are chemically unrelated to one another can disturb the normal development of the chick embryos by interfering with the utilization of one or more of these compounds It is understandable that those parts of the *embryo which are in most urgent need of nicotinamide* at the time of injection are the ones which are most susceptible

The question has been raised by some critics whether experimental observations made in lower animals can have any practical application in so far as the etiology and pathology of human congenital defects are concerned In a previous article (*Duraiswami* 1952) after discussing the various theories regarding the etiology of *human* congenital malformations the author put forward a hypothesis on the basis of his own experimental work as well as the observations made in experimental teratogenesis by other workers It is proposed to give a brief summary of the hypothesis and then show its clinical application as evidenced by various articles published more recently

The development of an embryo which is presumably guided by a succession of organizing processes may be interfered with during critical periods by genetic or environmental teratogenic factors These disturbances to the organizer system may in their turn produce

metabolic biochemical and other changes through the intervention of hormones and enzyme systems and thus interfere with the normal development of the embryo The resulting anomalies in development would not occur in a random assortment but tend to fall into certain categories corresponding to the critical stages of development of susceptible tissues and the quality and intensity of the noxious agent Developmental abnormalities may result not only from arrest of growth and differentiation of the embryo as a whole or some of its parts as was pointed out by *Stockard* (1920) but also from degeneration in tissues which had developed normally up to a certain stage as has been clearly demonstrated by the author in the case of insulin induced deformities (*Duraiswami* 1950 1952) and rubella induced lenticular lesions (*Tondury* 1951)

Now let us see how this general hypothesis can be applied to congenital orthopaedic deformities *In the life of the human embryo it is* possible to demarcate certain critical periods which are "peculiarly associated with catastrophic changes in the development of the skeleton (*Harris* 1933) The fourth and fifth weeks of intra uterine life are definitely associated with the development of the cartilage skeleton The seventh and ninth weeks present widespread calcification of the cartilage of the long bones as the main feature The orderly progression from the mesenhymatous condensation to cartilage and then through calcified cartilage to bone may be disturbed by genetic or environmental teratogenic factors as explained above and thus may result a variety of single and multiple skeletal deformities For example a suppression of proliferation of cells of the mesenchyme which is destined to form a limb will result in phocomelia (total absence of a limb) or ectromelia (absence of a part of a limb) If mitosis in the cartilage is suppressed during the fifth week of intra uterine life there may be *a complete failure of development of the cartilage* resulting in agenesis of any of the long bones such as the radius or the fibula or agenesis of the sacrum and coccyx In case there is inhibition of mitosis in the cartilage at one end of the bone there will be partial aplasia of the long bone such as the femur or the fibula Lastly varying degrees of interference with the nutrition or metabolic processes of the proliferating cells of the mesenchyme pre cartilage or cartilage or any disturbance to endochondral ossification may lead to a variety of abnormalities in a manner broadly analogous to the deformities *induced* experimentally with insulin and other teratogenic agents

The large variety of congenital orthopaedic and other defects th-

served more recently in the offspring of mothers who had taken varying doses of thalidomide (Distaval Contergen Tensival Valgraine Asmaval etc) in early pregnancy appear to the best clinical examples to prove the above hypothesis The congenital orthopaedic defects observed so far included ectromelia and phocomelia aplasia of the radius thumbs and fingers and major defects of the long bones The associated defects were atresia stenosis and malrotation of the gut absence of the appendix or gall bladder dysplasias of the external ears or eyes and defects in the heart or genito-urinary system Babies with these malformations were born in the Federal German Republic East Germany Sweden Belgium Switzerland Australia and the United Kingdom (Thalidomide and Congenital Malformations – Editorial – The Lancet February 10 1962 page 307) The actual number of such babies during the past few years is still unknown However *Lenz* (1962 (a))has ventured an estimate of at least 2000 and possibly more than 3000 in West Germany alone since 1959 In February 1962 Lenz stated (*Lenz* (1962 (b))) that he was then receiving information on from 3 to 10 new cases daily It is important to note that thalidomide which is innocuous to the mother like German measles may disturb the growth of limb buds and other tissues in the developing embryo during critical periods of their development According to ***Robertson*** (1962) thalidomide may seriously interfere with vitamin metabolism the B complex especially

After going through the latest literature on the teratogenic properties of thalidomide the author is struck with the close similarity between the major limb defects induced in the offspring of mothers treated with thalidomide in early pregnancy and those in chick embryos by insulin The similarity goes further in as much as insulin induced developmental defects in chick embryos can be prevented to a remarkable extent by treatment with suitable doses of nicotinamide after injection of insulin and the toxic effects of thalidomide such as glossitis with denudation of the mucous membrane seen in 25 per cent of the cases treated with the drug as well as polyneuropathy were due to vitamin B deficiency and these were readily controlled with prophylactic treatment with vitamin B complex On the basis of this clinical observation one is tempted to suggest that in the case of thalidomide also diphosphopyridine nucleotide mediated metabolic pathways may be involved in the origin of the congenital malformations and investigations on these lines may be rewarding

During the past three decades the role of maternal diabetes mellitus

in teratogenesis has been studied In the pre insulin era diabetic women had amennorrhoea and were frequently sterile *White* and co-workers (1939) showed that with the introduction of insulin the fertility of diabetics improved and the maternal mortality dropped to levels comparable with non diabetic women However the early and late foetal deaths fell only from 44 to 38 per cent and there is very definitely a higher incidence of congenital abnormalities *Oakley & Peel* (1949) reviewed 142 cases examined at King s College Hospital, London and found that the incidence of congenital anomalies was 6 3 per cent as compared with a general incidence of 0 94 per cent in 4829 deliveries in normal mothers They noted the following congenital defects in their series internal hydrocephalus congenital heart defects hemi vertebrae imperforate anus congenital dislocation of the hip cleft palate renal tract malformations absence of sacrum and coccyx and talipes equinovarus

More recently *Nassim & Jackson Burrows* (1959) have reported that a six month stillborn foetus whose mother had suffered from severe diabetes mellitus necessitating large doses of insulin during pregnancy showed multiple congenital deformities of the skeleton including abnormalities of the vertebral column and commented *Duraiswami s* observations may have a clinical application in pregnancies of diabetic women receiving large doses of insulin The work of *Duraiswami* (1952) is of particular interest to orthopaedic surgeons By injection of a single dose of insulin into fertilized hens eggs at an appropriate stage of development he was able to produce a great variety of malformations of the skeleton The ground substance of bone being composed in considerable part of mucopolysaccharides is profoundly disturbed in its metabolism during the period of action of insulin During that time a fault in the laying down of the skeleton occurs which is never corrected The moment of injection of insulin in terms of foetal development determines the part of the skeleton in which the defect will appear The action of insulin is most marked in areas of greatest skeletal activity

During the past decade great interest has been evinced by researchers in different parts of the world not only in inducing a variety of congenital defects in experimental animals including mammals by introducing chemical and hormonal teratogenic agents into the environment of the developing embryo but also in making successful investigations with a view to explain the modes of action of at least some of these agents in terms of disturbances to carbohydrate or protein meta

bolism or to specific biochemical processes. If we can definitely establish the causal relationship between such disturbances and the experimentally induced malformations, as the author is attempting to do in his present series of experiments with certain teratogenic agents, we will have found a way of investigating whether analogous changes in the metabolic, biochemical and other processes are responsible for congenital defects in man also. In this connection it is pertinent to note that *Villee* (1953) has studied the activity of various enzymes by incubating different tissues taken from twenty six human foetuses obtained at therapeutic interruption of pregnancy in a variety of substrates labelled with radioactive carbon. He is, in fact, trying to describe in biochemical terms the development of the various organs of the human being in the same way as the classical embryologist has described their anatomical differentiation. Work of this nature will go a long way to enable us to explain the etiology of human congenital anomalies on a scientific basis in terms of specific disturbances to normal metabolic and biochemical processes of the developing embryos during the "critical periods" of susceptible tissues and organs, caused by abnormal genes or environmental teratogenic factors. This will naturally pave the way for preventing at least some of the congenital defects in man in the same way as many of the developmental anomalies have been prevented in experimental animals.

SUMMARY

During the nineteenth century a new branch of experimental pathology known as teratogenesis or artificial production of malformations or monstrosities came into vogue mainly through the efforts of Geoffrey Saint Hilaire and Dareste. Some of the congenital defects induced in chick embryos by insulin, iso-nicotinic acid hydrazide and synermycin have been illustrated. The mode of teratogenic action of insulin has been discussed and its clinical application in the case of the congenital abnormalities induced in the offspring of mothers who had taken thalidomide in early pregnancy has been suggested.

RÉSUMÉ

Au 19ème siècle une nouvelle branche de pathologie expérimentale connue sous le nom de tératogenèse ou production artificielle de malformations ou de monstruosités a été à la mode principalement en raison

des travaux de Geoffres Saint Hilaire et de Dareste Certaines des défectuosités congenitales provoquees dans les embryons de poulets par l introduction d insuline d hydracide iso nicotinique de synermycine terramycine et cycloserine ont ete illustres l action teratogenic d l insuline est discutee et son application clinique dans le cas d anomalies congenitales chez les enfants de meres qui ont pris de la thalidomide au debut de la grossessse est suggeree

ZUSAMMENFASSUNG

Während des neunzehnten Jahrhunderts kam ein neuer Zweig d experimentellen Pathologie bekannt unter dem Namen Teratogenese oder künstliche Erzeugung von Missbildungen und Monstrositäten hauptsächlich infolge der Bestrebungen von Geoffrey Saint Hilaire u Dareste in Mode Einige der kongenitalen Defekte die in Hühnerembryonen mittels Insulin Isonikotinsäure Hydracid Synermycin Terramycin und Cycloserin hervorgerufen wurden sind erlautert worden Die Art der teratogenetischen Wirkung des Insulin wurde besprochen und ihre klinische Anwendung im Falle von kongenitalen Anomalien bei der Nachkommenschaft von Muttern die in fruher Schwangerschaft Thalidomid eingenommen hatten wurde vorgeschlagen

REFERENCES

1 *Duraiswami P K* Insulin induced skeletal abnormalities in developing chicken British Medical Journal 2 384 390 1950
2 *Duraiswami P K* Experimental causation of congenital skeletal defects and its significance in orthopaedic surgery Journal of Bone and Joint Surg 34 B 646-698 1952
3 *Duraiswami P K* Experimental teratogenesis with benzyl alcohol Preliminary report Bulletin of Johns Hopkins Hospital 95 57 67 1954
4 *Duraiswami P K* Comparison of congenital defects induced in developing chickens by certain teratogenic agents with those caused by i... Journal of Bone and Joint Surgery 37 A 277 294 1955
5 *Duraiswami P K* Experimental causation of congenital defects Proceedings of the Academy of Medical Sciences I No 3 19 ..
6 *Duraiswami P K* Experimental induction of congenital defect Proceedings of the Eighth Congress of the International Society of Orthopaedic Surgery and Traumatology held in New York (September 4 10 1960) (in press)
7 *Duraiswami P K* Experimental induction of congenital defects with isonicotinic acid hydrazide Indian Journal of Medical Research 49 631 634 19..
8 *Harris H A* Glycogen in cartilage Nature 130 .01 193.

9 *Harris H A* Bone Growth in Health and Disease London Humphrey Milford Oxford University Press 1933
10 *Lenz W* Thalidomide and congenital abnormalities Lancet January 6 1962 p 45 1962(a)
11 *Lenz W* Thalidomide and congenital abnormalities Lancet February 3 1962 p 271 1962(b)
12 *Nassim R & Jackson Burrows H* Modern Trends in Diseases of the Vertebral Column Butterworth & Co Ltd London 1959 p p 30-31
13 *Oakley W & Peel J* Proceedings of the 12th British Congress of Obstetrics and Gynaecology 1949
14 *Robertson W F* Thalidomide (Distaval) and vitamin B deficiency British Medical Journal March 17 1962 p 792
15 *Stockard C R* Developmental rate and structural expression an experimental study of twins Double monsters and single deformities and interaction among embryonic organs during their origin and development American Journal of Anatomy 28 115 1920
16 *Tondury G* Bulletin der Schweizerischen Akademie der Medizinischen Wissenschaften 7 325 1951
17 *Villee C A* Biochemical differentiation of human foetal tissues with age In Prematurity Congenital Malformation and Birth Injury p p 79-83 (Conference at the New York Academy of Medicine June 1952) New York Association for the Aid of Crippled Children 1953
18 *White P Titus R S Joslin E P & Hunt H* Prediction and prevention of late pregnancy accidents in diabetes American Journal of the Medical Sciences *198* 482 1939

FROM THE DEPARTMENT OF ORTHOPAEDICS, UNIVERSITY OF GOTHENBURG, SWEDEN (HEAD: PROF. CARL HIRSCH)

ORTHOPAEDIC PROBLEMS VIEWED IN THE LIGHT OF BIOMECHANICS

by

CARL HIRSCH

The biomechanical laboratory which today forms an integral part of the Gothenburg Department of Orthopaedic Surgery had its origin years ago in Professor Sten Friberg's clinic at Karolinska Institutet in Stockholm. Later the laboratory has followed us from Stockholm to Uppsala and again to Gothenburg. We can look back upon its development with satisfaction and gratitude. Professor Friberg's interest in research, his insight into technical problems and his gift for finding ways and means to finance new projects provided an indispensable support at the start. All of us who have been privileged to pursue this attractive subject join in expressing our appreciation and gratitude to Professor Sten Friberg.

One of the main functions of the skeleton is to provide stability, that is, to permit the body weight to be balanced so that a state of mechanical equilibrium can be achieved.

The laws of mechanics governing our planet must apply to biological questions too. It must be assumed that the movements of the body follow these laws. It is, indeed, a long established concept that form and structure of the skeleton are conditioned by the requirements set by the mechanical problems confronting the locomotive organs. Biomechanics is an interplay of given forms and external forces of organic structure and the law of gravitation.

It may reasonably be assumed that the inner architecture of the skeleton must be the issue of mechanical requirements. Knowledge of the physical properties of different skeletal structures should be helpful in elucidating the processes reflected in strains of various kinds. Determination of the magnitude of the forces acting on different skele-

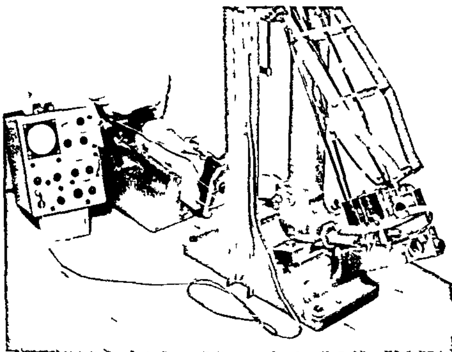


Fig 1

Experimental tudie n os calcis fractures (*Th ren*) A fresh autopsy specimen is mounted Muscles action n the foot is produced by pullies The foot is hit by a force An oscilloscope records the stress distribution while the fracture developes

tal regions under varying conditions should provide additional data of fundamental importance for a correct interpretation of these mechanical processes

Whereas we possess today a wealth of information about the morphology of the locomotive organs our knowledge of the biophysical significance of the various elements is considerably scantier Each movement requires a whole series of operations in every phase of which a state of mechanical equilibrium is established determined by the action called into play by a distribution of force Every external force tends to deform a body The form assumed by the body is determined by the opposing forces it can muster through its physical properties

When a skeletal part is placed under stress it is not only the bone itself which reacts – surrounding structures such as cartilage ligaments capsules musculature fasciae and fluid matter all join in a concerted effort to distribute the stress so as to achieve a state of equi

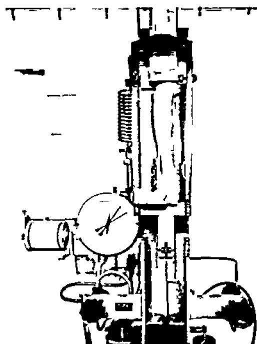


Fig 2
Experimental studies on the ant reactions to forces (*Lewis*)

librium Every mechanical stress consequently starts a chain reaction with the mechanical aim of providing relief

Presupposing this harmonious combination of forces to take place it must be assumed that it is governed by some form of co ordinating intelligence We know today that muscles capsules ligaments and tendons contain various kinds of sensitive terminal organs Skeletal and cartilaginous tissues were believed to lack this kind of organ Quite recently such informative organs have also been demonstrated in the trabecular structures of bone (*Miller*) It seems likely therefore that a mechanical stress on a skeletal structure elicits a chain of reactions in the surrounding soft tissues so that this part of the extremity as a whole contributes to the stress distribution required for equilibrium

Experimental research has shown that the distribution of the strain developed in a skeletal structure subjected to mechanical stress is influenced by muscular forces (*Pauwels Frankel Hirsch* among others) In other words the distribution of the strain can be directed by the action of the muscles

In such an interaction governing the transmission of force in the skeleton with the musculature taking an active part in the distribution of stresses it seems logical to assume the presence of "stress stimuli from the skeleton to the muscles The sensitive terminal organs which



Fig 3
Device for testing the ankle reactions to different types of movements under compression

have been demonstrated in the skeleton may very well form the anatomical contact between the skeleton and the muscular system.

The physical properties of the skeleton vary with age. Moreover they vary in different skeletal structures in the same human body depending on the functional requirements of a given skeletal region. The physical properties even vary in closely adjoining parts of the same bone (*Kalen, Forssblad*) indicating that mechanical function is highly dissociated and the transmission of force strictly bound to definite pathways. Certain regions have a greater weight bearing capacity than others (*Hisch & Brodetti*).

The physical properties of cartilage and its role in the transmission of force have prompted additional approaches (*Hirsch, Nachemson*).

Interpretation of the "stress routes" and the way in which they may be influenced is of value to clinical orthopaedics in the search for suitable reconstructive techniques. Arthrodesis is in fact one solution to a problem of force transmission. Arthroplasty, the most desirable operation for joint repair, presents problems which as yet cannot be resolved in terms of mechanics. Low friction, good stability and favour

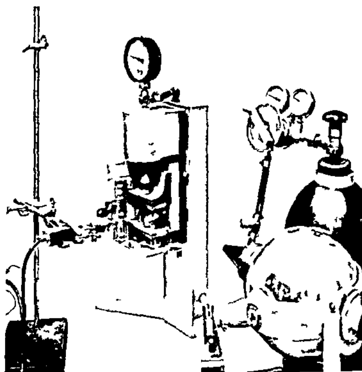


Fig 4

Intradiscal pressure measurements (*Nachemson*)

A mechanical electrical pressure transducer attached to a needle with plastic tub inserted into a disc The specimen is in a pneumatic clamp

able equilibrium conditions are some general desiderata Osteotomy myelotomy fasciotomy and myotenotomy too all include a component of force transmission the nature of which can at present not be analyzed in full detail because we lack methods for recording and checki the effect of these procedures As yet we are unable to measure strains in bone in vivo This is a goal which should be beyond our reach We must develop intra osseous strain receptors – something which th technician may be able to give us

In addition to the problems of distinct basic research which a bio mechanical laboratory must include in its program more palpable objects offer for clinical use A logical object of study is the mechanism producing common fractures because such experiments carried out on fresh autopsy material may reveal the extent of the injuries and suggest approaches to their management

The mechanism underlying medial neck fractures (*Frankel*) th

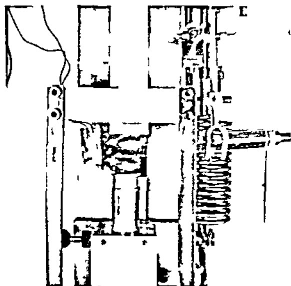


Fig 5
Mechanical problems in lumbar spine fusion (*Rolander*) Fresh autopsy specimen fused by graft fixed in plastic/glue grafts Straingauges inserted and connected with measuring bridges The specimen is tilted under *compression and the* stability of the construction is checked by electronic picups s in contact with various parts of the vertebral bodies

various forms of calcaneus fractures (*Thoren*) the injuries involving the ankle joint (*Lewis*) and the nature of vertebral fractures (*Perey*) are some examples of studies inspired by clinical biomechanics Technical problems of therapeutic interest constitute another logical field of inquiry Tests can be made to determine the effectiveness of various methods of lumbar osteosynthesis in eliminating intervertebral motion (*Rolander*) Internal fixation of femoral neck fractures still offers numerous problems (*Harvey Frankel Rydell Brodetti*) Altogether a well equipped laboratory offers ample opportunity for analysis of practical clinical problems

Prosthetics can no longer function without a biomechanical background The need for analysis of patterns and systems of motion becomes increasingly clear with every attempt to develop a new type of prosthesis High speed cameras to register patterns of motion and electromyographs to study intermuscular co-ordination have given us new testing methods At present we have great expectations of electronic recording of gait

Biomechanics as an orthopaedic research tool has since the early nineteen forties enjoyed an ever increasing interest perhaps mainly due to the new methods made available by technical progress and prompting application to problems of long standing clinical speculation During the early years of this century a lively clinical empiricism

produced a wealth of surgical approaches suggested by men tendi towards practical results The surgical orthopaedics which form th mainspring of our work today and for which we are greatly indebted, now invite further penetration

We learned that a well equipped biomechanical laboratory can pro vide a gratifying background for the orthopaedic surgeon who wishes to base his clinical management on the solid foundation of an experi mental technical approach

SUMMARY

The musculoskeletal system is discussed in the light of laws of me chanics The biophysical significance of various elements is of funda mental importance in elucidating the processes reflected in strains of various kinds

The program for the biomechanical laboratory is presented in short reports of work published and under progress Basic information about stress and strain analysis on bone and cartilage is mentioned Mechani cal problems in fracture mechanism and reconstructive bone surgery are revealed Illustrations of experimental set ups aim to elucidate the way the laboratory works

RESUME

Le systeme musculo squelettique est discute a la lumière des lois d la mecanique La valeur biophysique des differents éléments est d'u importance fondamentale pour eclaircir les processus qui se reflétent par des tensions de differentes natures

Le programme du Laboratoire bio mecanique est presente dans un court compte rendu des ouvrages publies et en cours de preparati Des informations de base concernant l analyse des effects de la force et de la tension sur les os et les cartilages sont mentionnes Les pro blemes mecaniques du mecanisme des fractures et de la chirurgie re contructive des os sont indiqués Des illustrations des expériences effectuees contribuent a montrer la maniere dont le Laboratoire tra vaille

ZUSAMMENFASSUNG

Das Muskel Skelettsystem wird unter Bezugnahme auf die Gesetz der Mechanik besprochen Die biophysische Bedeutung verschied ner

Elemente ist von grundlegender Wichtigkeit zur Aufklärung der Prozesse die sich bei Überbeanspruchung verschiedener Art äussern

Das Programm des biomechanischen Laboratoriums wird in kurzen Berichten uber die bereits veroffentlichten und die im Fortschreiten begriffenen Arbeiten vorgelegt Grundlegende Erkenntnisse der Analyse von Überbelastung des Knochens und Knorpels werden erwahnt Mechanische Probleme der Bruchmechanismen und der wiederherstellenden Knochenchirurgie werden aufgezeigt Illustrationen von experimentellen Einrichtungen bezwecken die Weise in der das Laboratorium arbeitet zu erlautern

REFERENCES

1 *Brodetti A* The weight bearing capacity of the femoral neck with solitary bone c st Acta Orthop Scand 26 81–98 1956

2 *Brodetti A* An experimental study on the use of nails and bolt screws in the fixation of fractures of the femoral neck Acta Orthop Scand 31 247 271 1961

3 *Fossblad P* Determination of elasticity modulus of bone Acta Orthop Scand 28 269–268 1959

4 *Frankel V* The femoral Neck Almqvist & Wiksells Boktryckeri AB Uppsala 1960

5 *Hansson J* Problem in amputees Under progress

6 *Harvey J P Hirsch C & Wilson P D* Experimental studies on the stability of internal fixation of femoral neck fractures in autopsy bone Surgical Forum vol IX 1959

7 *Hirsch C* A contribution to the pathogenesis of chondromalacia of the patella Acta Chir Scand vol XC Suppl 83 Stockholm 1944

8 *Hirsch C & Brodetti A* The weightbearing capacity of structural elements in femoral necks Acta Orthop Scand 26 15–24 1956–57

9 *Hirsch C & Brodetti A* Methods of studying some mechanical properties of bone tissue Acta Orthop Scand 26 1–14 1956

10 *Hirsch C & Frankel V* Analysis of forces producing fractures of the proximal end of femur J Bone & Joint Surg 42B 633–640 1960

11 *Hirsch C & Frankel V* The reaction of the proximal end of the femur to mechanical force Chapter 4 reprinted from Evans et al Biomechanical studies of the musculoskeletal system Charles C. Thomas Springfield Ill. 1961

12 *Hirsch C Ingelmark B E & Miller M R* The anatomical basis for low back pain To be published in Acta Orthop Scand

13 *Hirsch C & Nachemson A* Clinical observations on the spine in ejected pilots Acta Orthop Scand 31 135 145 1961

14 *Kalen R* Strain and stresses in the upper femur studied by the stresscoat method Acta Orthop Scand 31 103–113 1961

15 *Lewis J* Ankle reaction to force Under progress

16 *Miller M R* Personal communication
17 *Nachemson A* Lumbar Intradiscal Pressure Acta Orthop Scand Suppl 43 Munksgaard Kopenhamn 1960
18 *Nachemson A* Measurement of intradiscal pressure Acta Orthop Scand 28 269–289 1959
19 *Perey O* Fracture of the vertebral end plate in the lumbar spine Acta Orthop Scand Suppl 25 1957
20 *Rolander S* Mechanical problems in lumbar spine fusion Under progress
21 *Rydell N* A new apparatus for the measurement of the compression between two bony surfaces and a construction for compression in fractures of the femoral neck Acta Orthop Scand *31* 1–17 1961
22 *Thoren O* The mechanism of os calcis fractures Under progress

FROM THE DEPARTMENT OF ORTHOPAEDICS KAROLINSKA INSTITUTET STOCKHOLM (HEAD PROFESSOR STEN FRIBERG)

RIGIDITY OF IMMOBILIZATION OF TRANSVERSE FRACTURES

By

OLOV LINDAHL

The prime importance of immobilization in the treatment of fractures is reflected in the following quotations from major works in this field The aligned fragments must be *fixed immovably* in their correct position until the bones are properly united (*Bohler*) Protection of the growing cells from injury of movement by *complete immobilization* of the fracture is essential There is only one cause of non [illegible] of fractures with a continuous haematoma between the fragments [illegible] cause of non union is *inadequate immobilization* (*Watson-J*[illegible] "Non union is in most instances due to *incomplete fixation of* [illegible] ments (*Cave*) Since fractures heal by formation of new *bone* [illegible] the bone ends it is important that the *immobilization be as* [illegible] *solute as possible* Every movement between the fragment [illegible] an injury to the callus (*Key & Conwell*) The most con[illegible] for delayed union are (1) *Inadequate immobilization* per[illegible] tion and shearing stress to act at the fracture site (2) [illegible] tain adequate immobilization until union is complet[illegible] (Author s italics)

While it is thus generally accepted that immobilization [illegible] importance if union of a fracture is to be ensured [illegible] immobilization is not in all cases a condition of un[illegible] ribs and clavicle heal almost invariably without [illegible] and during constant though small movements T[illegible] for instance fractures of the femur treated by tra[illegible] quoted above should therefore be interpreted as [illegible] bilization will ensure a smaller risk of pseudart[illegible] the immobilization is

What is actually signified by the term imm[illegible] in which it is commonly used it means that [illegible]

absolutely still so that movement of one in relation to the other is prevented In the sense in which the term is used in mechanics complete immobilization cannot be reasonably achieved When a union is acted on by even quite small forces there will always be some movement although it may not be measurable by the usual techniques A more realistic approach to the problem would probably be to examine how large movements are permissible for the fracture still to be united in the most rapid and reliable way

Martz measured the force required to deform transverse fractures immobilized with Lane and Sherman fracture plates This however touches only the periphery of the problem The immobilization of fractures by external means (with plaster or splints) or internally (by osteosynthesis) would seem to have been little investigated

This article reports a study of the stability of transverse fractures of femur shafts immobilized by various osteosynthesis techniques

MATERIAL

Since it was intended in the first place to compare different methods of immobilization a pilot study was performed with pine wood rods of round section, 30 mm in diameter and 400 mm long These were sawn in half at right angles to the longitudinal axis after which they were immobilized in the following ways (i) One fairly thin Sherman fracture plate with 4 holes (no 6) (ii) two such plates of heavier type with 4 holes (no 5) (iii) one Sherman plate of heavier type with 6 holes (no 2) (iv) two such plates with 6 holes (v) three staples Further tests were conducted with fresh femurs from autopsy subjects The bone was bared of muscle and tendons and the marrow was washed out with hot water These shafts were sawn into two parts perpendicular to the axis and the fragments were immobilized with (vi) one Sherman plate of heavier type with 6 holes (vii) two such plates with 6 holes (viii) three staples (ix) Hoffmann transfixation in front Furthermore (x) a tibia was immobilized with a Hoffmann instrument after a transverse fracture with splintered ends had been caused by breaking (xi) a Kuntscher medullary clover leaf nail When 2 Sherman plates were used they were always set at right angles to one another The plates screws and staples were of vitallium the nails and Hoffmann instruments of stainless steel All the immobilizations were performed with usual surgical instruments A mechanically better immobilization could be made with the specimens than would be possible during an actual operation

METHOD

The rigidity of immobilization of a fracture can be tested by measuring the deformation resulting from the application of different forces for instance compression traction torsion and bending Fractures are usually not subjected to traction and the compressive force of muscular tonus is taken up entirely by the

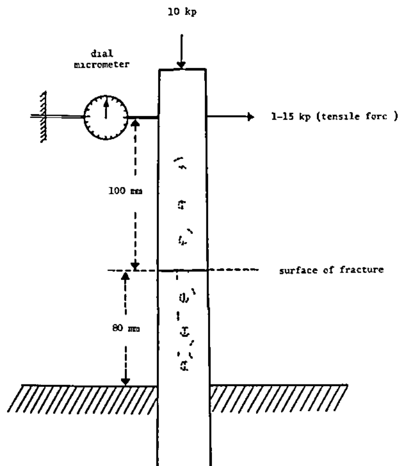
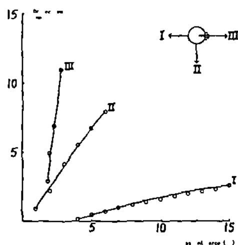


Fig 1
Arrangement for measuring the deflection of fractured femur and wooden shafts immobilized with various osteosyntheses

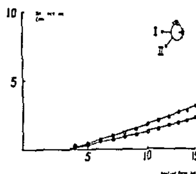
bone in the case of transverse fracture. The effects to be tested were therefore those resulting from bending and rotation.

With the bone held perpendicular in a vice 80 mm below the fracture a tensile force was applied perpendicular to the bone at a point 100 mm above the fracture. The deflection at this point was recorded on a dial micrometer (Fig. 1). The force was applied in two, three or four directions depending on the type of immobilization. The effect of torsion was examined in a similar manner, the angle of rotation for different moments being recorded. In all cases the specimen was compressed axially with a force of 10 kp[1] corresponding approximately to the force due to the tonus in the thigh muscles.

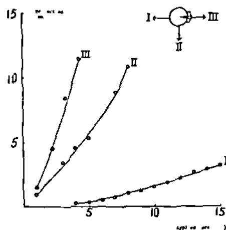
[1] One kilopond (kp) = 9.80665 newtons



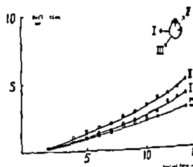
A Wooden rod
One 4 hole Sherman plate



B Wooden rod
Two 4 hole Sherman plates

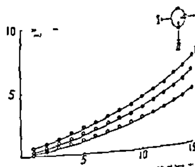


C Wooden rod
One 6 hole Sherman plate

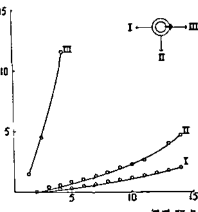


D Wooden rod
Two 6 hole Sherman plates

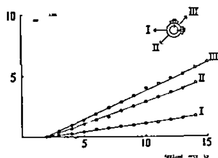
Fig 9 A–E
Relation between bending force applied at a point 10 cm from the surface of fracture *of the wooden rod and the deflection at the* same point Directions of loading are indicated in the plan



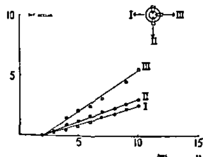
E Wooden rod Three staples



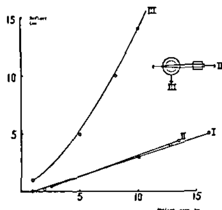
A Shaft of femur
One 6 hole Sherman plate



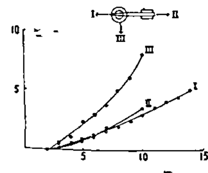
B Shaft of femur
Two 6 hole Sherman plates



C Shaft of femur Three staples



D Shaft of tibia Hoffmann instrument



F Shaft of tibia Hoffmann instrument

Fig 3 A–F
Relation between bending force applied at a point 10 cm from the surface of the femur shafts (A D) and tibia (F) and the deflection at the same point Directions of loading are indicated in the plan

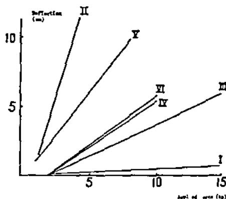


Fig 4

Comparison between osteosynthesis methods showing relationship between applied force and deflection of bone shafts (I) unfractured shaft of femur (II) fractured shaft of femur immobilized with one 6 hole Sherman plate (III) two such plates (IV) three staples (V) a Hoffmann instrument (sawn even fragments) and (VI) fractured shaft of tibia (splintered fragments) immobilized with a Hoffmann instrument The lowest recorded values (that is for bending in the direction of the least strength) have been taken as representative of each method.

Similar tests were performed with intact shafts of femur to find to what degree these were deformed by bending and torsional forces

In many cases the immobilization of the fracture was poor and because of definite deformation of the immobilization device the test had to be discontinued when the bending force was quite small In other cases a force of up to 15 kp was applied at a point 10 cm from the fracture this is equivalent to a bending moment of 150 kp cm It may be noted by comparison that when a straight leg with a femur fracture in the middle of the shaft is raised horizontally the immobilization device is subjected to a bending moment of 200 kp cm through the weight of the leg.

RESULTS

The deformation resulting from bending stress in different directions is shown in Figs 2–3 *A–E* It is seen that the rigidity depended on the direction of the applied force but that it varied little for a particular immobilization technique whether applied to the wooden rods or bone This indicates that the immobilization device was the weakest link in the system and that both wood and bone were stronger than this under the conditions of the experiments

A comparison of the different methods of immobilization where the lowest values for each method was recorded showed that the technique involving 2 Sherman plates set at right angles to one another provided the greatest rigidity but that even so the rigidity was considerably

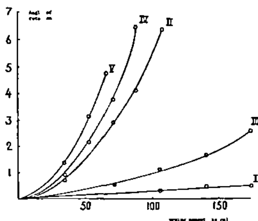


Fig 5

Comparison between osteosynthesis methods showing relationship between turning moment and resulting angle of rotation of (I) unfractured shaft of femur (II) fractured shaft of femur immobilized with one 6 hole Sherman plate (III) two such plates (IV) three staples and (V) a Hoffmann instrument The forces were applied and the angle of rotation recorded in the same plane as that in which the tensile force was applied (see Fig 1)

lower than that of the bone itself (Fig 4) Comparison of the torsional rigidity for the different methods of immobilization also showed that the use of two plates provided the best results (Fig 5)

It proved impossible to stabilize three available femur specimens with Kuntscher nails for the marrow space was wider than the diameter of the largest nail available—11mm moreover the space gradually widened distally so permitting the distal part of the femur to be greatly angled rotated and displaced laterally for several millimetres (Fig 6)

DISCUSSION

The experiments show that from a purely mechanical aspect the immobilization obtained with different osteosynthesis devices was far from perfect It is probably not unusual for a femur fracture shortly after operation to be subjected to a stress corresponding to that provided when the leg is raised from the bed The forces applied in these tests were considerably smaller than this and yet in several cases they gave rise to a displacement of more than 10 mm at a point 10 cm from the fracture

What is the effect of such a distorsion at the site of fracture? When a femur fracture immobilized with one Sherman plate was subjected to

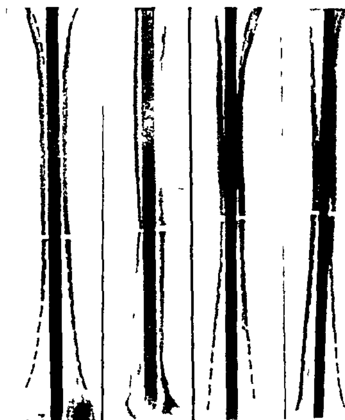


Fig 6

Radiographs of femur specimens which were immobilized with Küntscher na[...] The contour of the marrow space is indicated with broken lines

a force parallell to the plate surface (that is in the direction of the greatest strength) a bending moment of only 100 kp cm (one half of the moment acting when the leg is raised) was enough to cause a lateral deflection of 2 5 mm at the point of application of the force This caused the fracture to open 750 μm on the side opposite to that to which the force was applied this distance corresponds to one hundred times the diameter of a red blood corpucle It is hardly surprising that such lar[ge] movements often prevent the formation of a bridge of callus and lead to resorption of the bone fragments In this situation the subsequent course of healing will probably be different according to the osteosyn[thesis] technique used A Hoffmann instrument ensures constant appli[cation] of a certain pressure and hence continuous contact between the fragments so that these can gradually heal in spite of small movements The same applies to the Küntscher nail method On the other hand a

plate fixed in each of the bone ends will prevent contact between them after resorption has occurred and the steady course of healing will therefore be retarded One of the explanations of the poor results obtained with plates is probably that they were not stable enough to prevent small movements and resorption and then only prevented optimal contact between the bone fragments Of the other methods of immobilization it might be said that while they probably do not contribute to healing by stabilization of the union nor do they directly obstruct healing The fractures probably heal despite rather than because of this "immobilization

For internal immobilization which provides rigidity as poor as that observed in this study the term alignment or coaptation would seem to be more appropriate the term immobilization being reserved for methods in which the rigidity approaches that of the bone

Is there in fact any technique of stabilization that can be termed immobilization in this sense? The two plate method gave the best results of those tested but still movements occurred that were three times greater than those permitted by intact bone From this standpoint none of the methods tested could be regarded as effective means of immobilization In some special cases a Küntscher nail can be considered to provide such rigidity—namely when it completely occupies the marrow space on each side of the fracture this can occur only if the nail is of the same diameter as the space and if the fracture is situated within the upper third of the femur where the diameter may be constant for a distance of up to 10 cm It may thus be said that there is practically no experience of what chance there is of a shaft fracture healing and how rapidly if it were *completely* immobilized as is so strongly recommended in the text books From the theoretical standpoint it would seem that such immobilization would provide the best results

On the basis of these results a bone fracture plate has been designed that should provide a rigidity of an immobilized shaft fracture equivalent to that of the bone itself Tests on this plate are in progress and will be published in due course

SUMMARY

Experiments have been performed to compare the rigidity of different osteosynthesis devices (Sherman plates staples Kuntscher nails and Hoffmann instruments) Tests have been made in which transverse fractures of wooden rods and femur shafts immobilized by these different methods have been subjected to bending and torsional forces For

all the techniques the rigidity was low and unsatisfactory from a mechanical standpoint The best immobilization was obtained with 2 Sherman plates set perpendicular to one another

RESUME

Il a ete effectue des experiences dans le but de comparer la n du materiel utilise pour l osteosynthese (plaques Sherman crampons clous Küntscher et instrument Hoffmann) Des essais ont ete faits dans lesquels des fractures transversales de tiges de bois et de corps du femur immobilisees par ces differentes methodes ont ete soumises a des forces de flexion et de torsion

Pour toutes les techniques la rigidite etait faible et insatisfaisante du point de vue mecanique La meilleure immobilisation a ete obtenue avec 2 plaques Sherman placees perpendiculairement l une par rapport a l autre

ZUSAMMENFASSUNG

Versuche wurden ausgeführt um die Widerstandskraft verschiedener Vorrichtungen zur Osteosynthese (Shermanplatten Haspen Küntscher Nägeln und Hoffmann Instrumenten) zu vergleichen Proben wurden vorgenommen in denen Querbrüche von Holzstaben und Femurschäften die mittels dieser verschiedenen Methoden fixiert worden waren beugenden und drehenden Kraften unterworfen wurden Bei allen Techniken war die Widerstandskraft gering und vom mechanischen Gesichtspunkt unzufriedenstellend Die beste Ruhigstellung wurde mittels zweier Shermanplatten erreicht die senkrecht aufeinander gesetzt waren

REFERENCES

Bohler L Die Technik der Knochenbruchbehandlung Vienna Verlag von Wilhelm Maudrich 1953 vol 1 p 17

Cave F Fractures and Other Injuries Chicago The Year Book Publishers Inc 1958 p 45

De Palma A The Management of Fractures and Dislocations Philadelphia and London W B Saunders Company 1959 p 43

Key J & Conwell F The Management of Fractures Dislocations and Sprains Ed 3 St Louis C V Mosby Company 1942 p 65

Mart C J Bone Joint Surg 38 4 877–834 1956

Watson-Jones R Fractures and Joint Injuries Ed 3 Edinburgh E & S Livingstone 1944 vol 1 pp 5 and 13

THE UTILIZATION OF MOVEMENT IN JOINT ROENTGENOGRAMS

By

PAUL C. COLONNA

Emeritus Professor of Orthopaedic Surgery

I have a feeling of hesitancy in presenting such a subject before a group of clinicians and I hope you will forgive me choosing such a subject that will to many of you only be review of methods that you daily apply and fully appreciate. However, I have thought that by presenting an outline of this subject it may stimulate all of us to pool our interests and review some new and some old diagnostic methods of requesting roentgenograms. Those of us that deal much in bone and joint work learn not only to appreciate the standard positions for roentgenograms but frequently have evolved practical methods in showing by unusual methods what we may clinically suspect—yet not demonstrate by routine positions. We will omit the technical difficulties involved by the trained roentgenologist for this is certainly outside the scope of an orthopaedic surgeon to discuss. I may say that we as orthopaedic surgeons only ask of our friends the roentgenologists to always produce excellent pictures in the minimum amount of time and without errors of interpretation!

For some time now I have been impressed with the advantage of utilizing what has been called the functional test to increase our information regarding problems that arise from disabilities of the bones and joints. By this method we may graphically demonstrate ranges of normal and abnormal skeletal motion that can be produced and that may aid in the solutions of our problems. We are all aware of the value of utilizing tissue movement for this is accomplished daily in the use of the fluoroscope *for cardiac and G.I. problems. In the osseous system* however the general conception of a rigid bony framework has often caused us to overlook valuable data that can be elicited from filming the joints if we utilize movement.

In pathological states involving the bones and joints there are

number of conditions in which excessive mobility can be demonstrated. The extent and variety of bone and joint lesions in which this principle can be utilized will depend both upon the ingenuity and the close coöperation between the roentgenologist and the orthopaedic surgeon.

It may be remembered that in ligamentous relaxations such as recurrent dislocations or ligamentous tears in various regions of the body the method is of great value. It may be accomplished by exerting force manually on the affected joint so as to record an appreciable amount of joint displacement, such as in an acromioclavicular dislocation, strains at ankles, knees, etc. Requesting oblique views of the wrist will also more clearly demonstrate a fractured carpal scaphoid. Bending the spine in flexion, in extension and laterally to the right and left will demonstrate a suspected pseudoarthrosis following spinal or lumbosacral fusion. These and many other examples may come to mind when we focus attention on this problem. (The roentgenogram should therefore be taken both before and after force or motion is applied. The unusual laxity seen sometimes in joint structures may be present in certain normal individuals but in these one can easily demonstrate a general relaxation of all the joints. In these instances, interpretation must be largely to the clinician's judgement to decide whether the laxity is normal or abnormal.)

In the spine let us consider the chronic lumbosacral strains with no primary bone pathology which present an increased lumbosacral angle and give rise to stress and strain, causing persistent low back pain. By making lateral standing and supine views, often definite abnormal movement at the lumbosacral joint may be demonstrated, indicating the degree of instability.

Another example demonstrating this method is by taking preoperative x-rays in cases of idiopathic scoliosis. Here the bending plates of the spine are of great value in deciding the progressive nature of the curve. We also routinely take the patient's spine, supine, sitting and then standing with the leg inequality compensated by a block under the feet. In the supine position by bending the body strongly to the right and to the left to demonstrate and illustrate the initial and secondary curves which aid in choosing the operative site or sites for operation as well as decide the extent of the vertebral fusion that may be necessary. The functional test can also be of help in therefore evaluating certain types of operative procedures on the spine, particularly spine fusion and lumbosacral fusions. It is sometimes very difficult or impossible clinically to decide whether a fusion operation has resulted

in actual bony union but if two lateral films are taken—one with the spine extended and the other in the flexed position and two a p with lateral bending to the right and left conclusive evidence regarding the integrity of the operative fusion can be obtained

Again if relaxation or disease at the sacro iliac joint is suspected x rays of the symphysis pubis show movement This may be accomplished by having the weight shifted first upon one foot and then the other while an x ray of the symphysis pubis is being taken If movement occurs at this joint it is of some diagnostic importance in evaluating the abnormal motion in the sacro iliac joint

Among the disabilities of acquired origin are those resulting from fracture of the neck of the femur and here the dissolution of bony continuity can often be suspected clinically but one can strikingly demonstrate the range of mobility in non union or delayed union of the neck of the femur by the so-called push and pull roentgenograms We can demonstrate frank non union or even whether the head fragment is firmly fixed to the neck by fibrous or bony union by the method of abducting and adducting the lower extremity A comparison of these films will show whether the head fragment moves with the movement of the shaft and this may be of real aid in deciding upon the presence or lack of union Another very important point to always look for in these cases of hip joint disability of long standing is whether the joint space is narrowed obliterated or roughened and whether the socket is of normal depth or the socket is satisfactory in depth It is only fair to say that an a p view of the hip is very informative but a good frog position if it can be possibly obtained is also of great value For some years now we have been taking an oblique view of the lumbosacral area and found it helpful for hip joint information with hip cases after surgery in conditions of congenital dislocation of the hip or in detecting early and definite changes in the head and acetabula very early in the Perthes disease syndrome or in arthritis of the hip joint

CONGENITAL DEFORMITIES

It is however in the congenital lesions of the bones and joints that this method of taking roentgenograms is of particular aid and various techniques may occur to the reader It can give a very definite index regarding the degree of anteversion of the head and neck and if this degree is abnormal it may be of practical value to correct during the course of treating the congenitally dislocated hip Ordinarily we can

FROM THE ORTHOPAEDIC CLINIC, UNIVERSITY OF LUND
(CHIEF: PROFESSOR C. WIBERG)

TWO SOURCES OF ERROR IN MEASUREMENT OF THE ANTEVERSION ANGLE OF THE FEMUR

By

HÅKAN BRATTSTRÖM, M.D.

Measurement of the so called anteversion angle of the femur, i.e. the angle formed by the longitudinal axis of the femoral neck and the frontal plane of the posterior part of the femoral condyle in a person in the erect position, has attracted much interest. The angle is said to be normally about 12° in adults and about 30° in newborns. In children with congenital dislocation of the hip or acetabular dysplasia this angle is often increased and may then be of diagnostic and prognostic importance. Knowledge of the size of the angle is also therapeutically useful because several authors believe that if the angle exceeds a certain value, correction with rotation osteotomy is indicated.

Several methods have been described for determining this anteversion angle roentgenologically. Most of the methods used in Scandinavia are based on the principle that the patient is allowed to lie on an examination table with the lower legs hanging over the edge of the table, the central beam directed vertically. By rotating the femur inwards it is seen on the fluoroscopic screen or in serial films when the femoral neck is projected to its maximum length on the screen or the film, i.e. when the longitudinal axis of the femoral neck is horizontal. The lower leg, hanging over the edge of the table serves as an indicator; the number of degrees it deviates from the vertical is taken as a measure of the degree of anteversion (figs. 1 A and B).

This examination method is based on two assumptions:

1) that the posterior plane of the condyle in the position in question is horizontal (fig. 1 A);
2) the absence of any substantial instability of the knee joint flexed at about 90°.

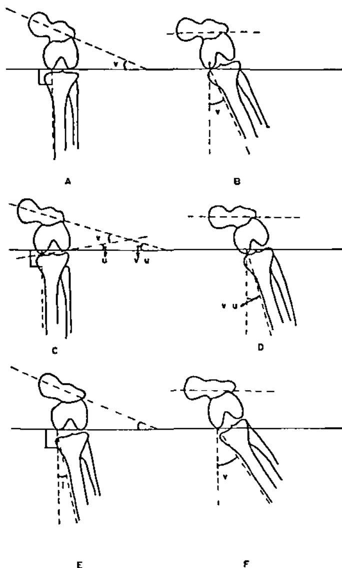


Fig. 1

A and B show the ideal theoretical condition in measuring the anteversion angle ([illegible]). C and D show the influence of the position of the condyles: the line through the condyles forms an angle of u with the horizontal line and we get a value of the anteversion angle which is [illegible] u smaller than the real one. E and F show the influence of the instability of the flexed knee: we get a value of the anteversion angle which is [illegible] (see text) greater than the real one.

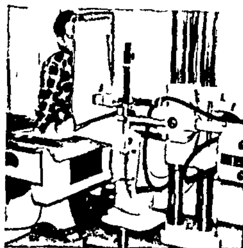


Fig. 2.
The patient on the table, the lower leg fixed, a cassette in the knee fold.

Ad 1. Fifty males and fifty females were examined roentgenologically under standardized conditions, and the position of the femoral condyles in relation to the horizontal line was determined. The patient was sitting on an examination table with the knees flexed about 90°, the lower leg was vertical (medial tibial condyle and medial malleolus in same vertical line (fig. 2)). The cassette was placed in the knee fold, the roentgen tube was centered upon the joint space. The table was provided with a metal wire which is projected on to the film and represents the horizontal line.

It was then found that the level of the medial condyle is nearly always lower than that of the lateral condyle. In only 5 of these 100 persons with healthy knees was the medial condyle in the same horizontal plane as the lateral; in the remaining 95 the posterior line of the condyle formed an angle of 1–8° with the horizontal line, on the average 3° in the males and 4° in the females (fig. 1 C). Similar observations were made in 15 children below 12 years.

The angle indicated by the longitudinal axis of the lower leg when the axis of the femoral neck is horizontal is thus not the true anteversion angle (figs. 1 C and D). The true angle is 3–4° greater. Here then is a systematic error in the measurement of the anteversion angle by the method described, an error which gives a false low value for the angle.

Ad 2. When the leg is stretched the knee is stable. On flexion of the knee the ligaments are stretched and relaxed according to a com

plex pattern but a certain degree of lateral instability of the flexed knee is always demonstrable I made an examination of the degree of lateral instability of the knee flexed about 90

To fix the femur is difficult I therefore fixed the tibia and allowed the femur to be movable See fig 2 If the patient illustrated in the figure for example is instructed to try to pendulate the fixed foot medially he contracts the outward rotators of the femur and the femur rotates outwardly as much as the instability of the knee will allow and the medial joint space is widened And reversely if the patient tries to pendulate the foot laterally the lateral part of the joint space is widened

When measuring the angle of anteversion it is the medial widening that is of interest and may influence the result An example the starting position is given in fig 1 A i e the condylar plane is horizontal and the lower leg is vertical We now allow the foot to pendulate laterally to rotate in the hip and to get the femoral neck horizontal In the presence of an instability of say i medially the foot will pendulate laterally i without any associated movement of the femur (fig 1 E) not until afterwards does the pendulation of the lower leg become a direct indicator of the rotation of the femur and thereby provide a possibility of measuring the anteversion angle The angle measured is thus the sum of the true anteversion angle and the instability angle (fig 1 F)

We measure the anteversion angle of hips which are often painful and their range of movement limited It appears reasonable to assume that because of the pain the degree of instability is utilized to a maximum before the femur begins to rotate I have examined 15 children below 12 years for this instability both laterally and medially All had clinically normal hips and knees

The results varied widely *inter alia* because of the varying capacity of the children to cooperate but the slightest medial instability noted was 2 and in 2 of the patients it was more than 10 from the starting position The lateral instability was usually a few degrees more

Here too then is a systematic error this time in a positive direction i e the method gives a falsely large anteversion angle

These two errors partly neutralize one another but I believe the latter source of error to be so great as to justify the following recommendations

1 The anteversion angle should not be measured in legs with acute pain in the *hip and consequent resistance to movement*

2 Before rotation osteotomy is done instability of the knee should

be judged clinically or roentgenologically in order to check that the patient does not belong to the type with a marked medial instability of the knee joint resulting in the measurement of a falsely large anteversion angle.

SUMMARY

The author calls attention to two sources of error in measurement of the anteversion angle of the femur, one of which may be of practical importance. When making such a measurement on patients with a painful fixed hip and/or on patients with marked instability in the knee joint one have to pay attention to this error.

RÉSUMÉ

L'auteur attire l'attention sur deux sources d'erreur dans la mensuration de l'angle d'antéversion du fémur dont l'une peut présenter une importance pratique. Lorsqu'on procède à de telles mensurations chez un malade qui a une hanche douloureuse fixée et/ou chez des malades présentant une instabilité marquée de l'articulation du genou il faut prendre garde à cette erreur.

ZUSAMMENFASSUNG

Der Verfasser macht auf zwei Fehlerquellen bei der Messung des Anteversionswinkels des Femurs aufmerksam, von denen eine praktische Bedeutung haben kann. Wenn solche Messungen an Patienten mit schmerzhafter fixierter Hüfte und/oder an Patienten mit ausgesprochener Instabilität des Kniegelenkes vorgenommen werden, dann muss man diesen Fehler berücksichtigen.

REFERENCES

Billing, L. Acta Radiol. Suppl. 110, 1954.
Bragard, K. Z. chrift Orthop. Chir. Beilageheft 57, 113.
Brantigram, O. C. & Voshell, A. F. J. Bone & J. Surg. 23, 44, 66, 1941.
Hjortsj, K. H. Bi. rel. capparaten. Gleerup, Lund 1959.
v. Lanz, T. & Wachsmuth, W. Praktische Anatomie, Springer, Berlin 1938.
Palmer, I. Acta Chir. Scand. Suppl. 53, 1938.
Pliton, F. J. Bone & J. Surg. 35 A, 48, 54, 1953.
Steels, B. & Mineas, B. Quart. Bull. Northwest Univer. Med. School 30, 43, 48, 1956.
Trevor, D. Proc. Roy. Soc. Med. 51, 1045, 48, 1958.

SÉQUELLES DOULOUREUSES DES LÉSIONS TRAUMATIQUES DES NERFS PÉRIPHÉRIQUES

Par

R. Merle d'Aubigné

L'étude actuelle a porté sur les séquelles douloureuses de lésions des nerfs périphériques opérées à la Clinique Orthopédique et Réparatrice de l'Hôpital Cochin entre 1950 et 1960. Elles sont au nombre de 185.

Il s'agit dans 102 cas de sections nerveuses complètes. Ce chiffre comprend 51 séquelles douloureuses d'amputation. Dix cas sont des lésions incomplètes, soit qu'il s'agisse d'une section partielle, soit d'une lésion dans la continuité avec une conservation partielle de la conductibilité. 42 cas enfin concernant des nerfs macroscopiquement intacts mais entourés de tissus plus ou moins altérés. Il reste 31 observations dans lesquelles la lésion n'a pu être précisée, car le compte rendu initial n'était pas explicite et l'intervention secondaire a porté à distance.

INTERVENTIONS LOCALES

Parmi les interventions locales, nous avons employé la suture, la neurolyse et la neurotomie.

Toutes les fois qu'il s'agissait d'une section du nerf et que la suture était possible, nous l'avons pratiquée en obtenant le rapprochement de bouts sains par une dissection étendue du nerf et au besoin, pour le nerf cubital, par une transposition (30 cas).

Lorsque l'exploration du nerf nous a montré une lésion en continuité et s'il existait des signes de conservation physiologique au moins partielle, nous nous sommes contentés d'une neurolyse libérant le nerf soigneusement *et le plaçant dans des tissus sains (87 cas).*

Dans les syndromes douloureux sur moignons d'amputation, nous avons généralement utilisé dans un premier temps, tout au moins lorsqu'il s'agissait d'une douleur localisée, la neurotomie, c'est-à-dire la découverte du nerf en tissu sain, sa résection en laissant simplement

l'extrémité supérieure du nerf se rétracter dans des tissus normaux. Cette intervention a été faite dans 62 cas.

SYMPATHECTOMIE PRÉGANGLIONNAIRE

Nous pratiquons cette opération depuis 1945. La présente série qui va de 1950 à 1960 comporte 38 sympathectomies dites préganglionnaires portant soit sur la chaîne dorsale haute lorsqu'il s'agit du membre supérieur, soit sur la chaîne lombaire haute lorsqu'il s'agit du membre inférieur.

La sympathectomie lombaire n'a été pratiquée que 7 fois par incision oblique thoraco-lombaire centrée sur la 12ème ou sur la 11ème côte. Nous avons exérésé les premiers ganglions lombaires en remontant jusqu'au 12ème et cherchant à atteindre le 11ème ganglion thoracique. L'exérèse de ce ganglion paraît indispensable d'après *White* et Smithwick lorsque l'on s'attaque à des douleurs intéressant la racine du membre inférieur.

La sympathectomie dorsale mérite que l'on s'y arrête un peu plus. Elle doit porter sur les 2è, 3è et 4è ganglions thoraciques ou plutôt sur la chaîne thoracique au niveau des 2è, 3è et 4è côtes car les renflements ganglionnaires ne sont pas toujours très bien marqués. Dans l'opération décrite par *White* et *Smithwick*, on enlève avec le ganglion la partie proximale du nerf intercostal et les rameaux communiquants blancs.

Nos interventions ont été faites 22 fois par voie dorsale et ont comporté 8 fois la resection des nerfs et l'ablation des ganglions sympathiques, 6 fois la section isolée des nerfs intercostaux et 8 fois la seule exérèse des ganglions sympathiques. 16 malades ont été opérés par voie transpleurale par une incision faite au niveau de la 3ème côte et ont comporté l'excision isolée de la chaîne sympathique.

RÉSULTATS D'ENSEMBLE PAR INTERVENTION

Les résultats de ces différentes interventions pour l'ensemble des séquelles douloureuses des lésions des nerfs périphériques sont assez décourageants en ce qui concerne les interventions locales; ils sont résumés dans le tableau X. Les résultats des interventions locales, sutures, neurolyses et neurotomies, ont été précisés 15 jours après l'opération et 6 mois après l'opération. Pour le résultat des sympathectomies, le recul de 6 mois nous a paru trop court et nous n'avons retenu que les résultats observés au bout d'un an. Le tableau montre pour

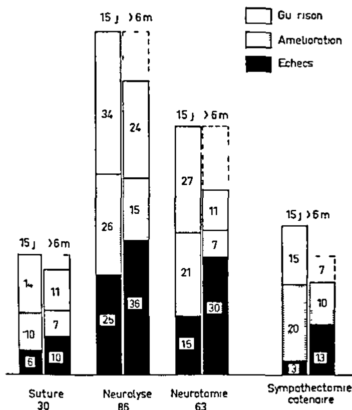


Fig 1

chaque operation la comparaison des resultats immediats et des resultats eloignes ceux-ci ne pouvant d ailleurs pas etre considéres comme toujours definitifs

La suture montre sur 30 observations 14 guerisons complètes 10 améliorations importantes et 6 echecs immediats Mais si nous revoyons ces malades plus tard c est a dire au bout de 6 mois 2 ont ete perdus de vue il ne nous reste plus que 11 guerisons complètes et 7 améliorations importantes mais nous retrouvons 10 echecs

Pour la neurolyse les résultats sont analogues sur un plus grand nombre de cas puisque nous avons 86 neurolyses Le chiffre des echecs

qui n'était que de 26, 15 jours après l'opération s'élève à 36 au bout de six mois. Les améliorations importantes étaient de 26 précocement et tombent à 15 au bout de 6 mois ; par contre le nombre des résultats favorables reste relativement stable puisque nous avons encore au bout de 6 mois 24 guérisons complètes. 11 malades améliorés ou guéris au dernier examen ont été perdus de vue.

Pour les neurotomies enfin un écart sensiblement comparable apparaît avec 15 échecs primitifs et 15 récidives de douleurs dans les six mois, soit 30 échecs au bout de six mois et une proportion d'améliorations qui se trouve fortement diminuée par le nombre assez élevé des cas perdus de vue.

L'étude des observations montre cependant que les guérisons complètes immédiates restent stables dans l'ensemble, mais que les malades qui ne sont qu'améliorés ont beaucoup de chance de voir réapparaître leurs douleurs dans les mois qui suivent l'intervention.

Si nous étudions maintenant les résultats de la sympathectomie, ils paraissent un peu plus favorables. En effet, sur 38 sympathectomies nous avons 35 guérisons ou grandes améliorations immédiates et seulement 3 échecs ; au bout d'un an les récidives ne s'élèvent qu'à 10, ce qui nous donne 13 échecs au bout d'un an. Il est vrai que 8 malades ont été perdus de vue et il ne nous est pas possible, malgré les probabilités dans ce sens, de les compter parmi les succès.

La constatation d'un nombre si important d'échecs immédiats et de récidives nous a porté à étudier de plus près les syndromes douloureux pour lesquels ces interventions avaient été faites, afin de chercher à dégager les indications respectives des différentes thérapeutiques et les chances de succès de l'action chirurgicale suivant les symptômes présentés par les malades.

Dans les nombreux travaux parus sur cette question des douleurs après lésion nerveuse, deux syndromes sont bien individualisés : ce sont le fantôme douloureux des amputés d'une part, la causalgie vraie d'autre part. Mais il existe d'autres syndromes douloureux ne répondant pas au caractère de ces algies bien individualisées et qui sont néanmoins très persistants, d'un traitement très difficile, et qui pour ces raisons ont été par un grand nombre d'auteurs confondus. C'est ainsi que, dans plusieurs travaux, le terme général de causalgies finit par désigner toutes les douleurs rebelles après lésions des nerfs périphériques.

LES SYNDROMES DOULOUREUX

L'un de nous s'est attaché dans sa thèse à analyser de près les syndromes douloureux présentés par les malades sur lesquels nous sommes intervenus et a pu les classer en cinq syndromes différents que nous rangerons ici par ordre de gravité croissante. Ce sont :

I. — *Névromes douloureux simples*	98 cas	
II. — *Hyperesthésie douloureuse*	20 cas	
III. — *Algies ascendantes*	25 cas	
IV. — *Fantôme douloureux*	12 cas	
V. — *Causalgies vraies*	30 cas	Total 185 cas

I. — *Le névrome douloureux simple* est caractérisé par une douleur localisée en un point, quelquefois spontanée, mais plus souvent provoquée et ceci parfois plus par l'effleurement que par le contact appuyé. Cette douleur présente des irradiations, mais elles sont purement descendantes dans le territoire du nerf intéressé sans tendance à la diffusion vers la racine et sans que l'excitation portée sur le territoire du nerf lésé soit douloureuse.

II. — *L'hyperesthésie douloureuse* est caractérisée par l'existence d'une hyperesthésie dans le territoire sensitif sous-jacent à la lésion nerveuse, telle qu'une excitation qui normalement n'entraîne aucune douleur, crée chez le malade une souffrance insupportable. Cette douleur peut être provoquée par un simple frôlement ou par la pression appuyée. Sur les 20 cas où ce syndrome a été constaté, la moitié siègent au membre inférieur. Les nerfs le plus souvent affectés sont le sciatique, le tibial postérieur et le saphène externe. Presque toujours il s'agit de plaies traitées par suture. Au membre supérieur, le nerf le plus souvent intéressé est le nerf médian.

III. — *Algie ascendante.* — Dans cette 3ème catégorie nous classons les douleurs caractérisées par l'existence d'irradiations ascendantes spontanées ou provoquées remontant le long du trajet du nerf, pouvant atteindre la racine du membre et déborder sur les ceintures. La douleur est le plus souvent spontanée, augmentée non seulement par la pression au voisinage de la lésion nerveuse mais une zone beaucoup plus grande, et également par les mouvements, les secousses.

IV. — *Membre fantôme* : les amputés perçoivent habituellement pendant un certain temps le membre absent avec des sensations plus ou

moins désagréables. Cette illusion s'estompe en règle assez vite mais dans certains cas les souffrances ressenties dans le membre fantôme persistent et s'aggravent. Elles sont spontanées mais souvent accrues ou modifiées par la pression en des points précis du moignon correspondant à des névromes. Leur siège relativement fixe intéresse surtout l'extrémité du membre absent. Leur caractère les fait comparer par le blessé à des brûlures, des broiements ou des attitudes de crampes.

V. — *Causalgies vraies* : il s'agit d'un syndrome tout à fait particulier. La douleur est ici très intense, comparée habituellement à une brûlure ou à une sensation d'électricité. Elle est spontanée, permanente, avec des redoublements paroxystiques. La palpation de la région atteinte, le simple frôlement plus que la pression appuyée exagèrent considérablement la souffrance. Mais surtout deux faits caractérisent la causalgie : *elle déborde en étendue le territoire du nerf lésé*, pouvant atteindre le thorax et le cou s'il s'agit du membre supérieur ; toute la moitié du corps est parfois intéressée ; enfin et surtout elle est constamment *aggravée par les excitations physiques et sensorielles, les émotions*.

La causalgie est apparue 3 fois d'emblée après le traumatisme ; dans les autres cas, l'intervalle libre ne dépassait pas six semaines. Dans la moitié des observations, le nerf médian était en cause, surtout intéressé par des plaies de la main et des doigts.

Les sections nerveuses complètes sont les plus nombreuses, mais le syndrome peut être vu dans les lésions incomplètes.

RÉSULTATS PAR SYNDROME

L'étude comparée des résultats dans ces différents syndromes nous a montré que leur pronostic post-opératoire était complètement différent et que l'on pouvait les répartir en trois groupes.

Dans un premier groupe qui comprend *les névromes douloureux simples*, les succès des interventions locales, sutures, neurolyses, neurotomies sont la règle, l'échec l'exception. Les quelques échecs qui se sont produits ont été repris avec succès par sympathectomie.

Le deuxième groupe qui réunit les *hyperesthésies douloureuses, les algies ascendantes et les fantômes douloureux* que nous aurions tendance à appeler syndromes douloureux à retentissement sympathique, les résultats sont beaucoup plus mauvais en ce sens que les opérations

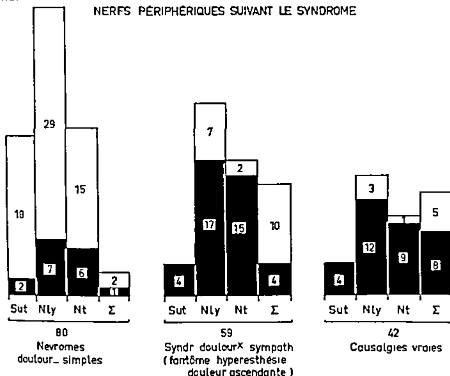


Fig. 2

locales présentent un nombre considérable d'échecs, la sympathectomie au contraire donne des résultats assez fidèles.

Dans le 3ème groupe, enfin, de beaucoup le plus grave et le plus difficile, *les causalgies vraies*, l'échec des interventions locales est presque constant, les succès des sympathectomies sont rares.

Le tableau n° 2 résume l'ensemble de ces résultats. Le nombre des cas est différent des chiffres précédents car seuls sont retenus les résultats éloignés et certains malades ont subi plusieurs interventions. On peut y voir que dans le névrome douloureux la suture donne 90 % de succès, la suture, la neurolyse et la neurotomie ensemble 80 % de succès. Dans cette catégorie, [illegible] cas classés comme échec initialement ont été revus, après quelques années, ayant cessé de souffrir.

Dans la deuxième catégorie où nous avons réuni fantômes douloureux, hyperesthésies douloureuses et algies ascendantes, la suture n'a donné aucun succès sur 4 cas, la neurolyse seulement 7 succès sur 24

et la neurotomie 2 succès sur 17, soit 20 % de succès des opérations locales. Par contre la sympathectomie nous a donné 10 succès sur 14 cas, soit 71 % des cas. Un seul des cas classé comme échec s'est amélioré secondairement et a été revu plusieurs années après guéri.

Enfin dans la 3ème catégorie de causalgies proprement dit les *résultats sont à vrai dire presque désespérants* : aucun succès de la suture, 3 succès sur 15 neurolyses, 1 succès sur 10 neurotomies, la sympathectomie a été pratiquée 13 fois, elle a donné 5 succès et 8 échecs par récidive.

Ce tableau est sévère probablement de façon excessive. En effet tous les cas qui n'ont pas été améliorés ont été comptés comme échecs quelque fut la durée d'observation ; au contraire n'ont été retenus comme succès que les bons résultats revus 6 mois ou un an après l'intervention. Il n'en reste pas moins que le nombre d'échecs des différentes thérapeu*tiques reste très important*.

Cependant les chances d'amélioration par les interventions locales, sutures, neurolyses et neurotomies ne sont pas négligeables dans les névromes douloureux simples. Dans ces indications, elles ne semblent pas avoir eu pour conséquence l'apparition de syndromes douloureux à retentissement sympathique comme on l'a dit quelquefois. Ces interventions sont parfaitement logiques et doivent être tentées.

Dans les hyperesthésies et douleurs ascendantes, la neurolyse et la suture peuvent être indiquées pour traiter les symptômes de déficit *moteur ou sensitif*, mais ces techniques ne peuvent pas être considérées comme un traitement du syndrome douloureux et risquent même de l'aggraver. Nous sommes de même extrêmement réservés sur les indications de la neurotomie dans les fantômes douloureux.

Dans la plupart de ces cas nous croyons qu'il faut s'orienter de bonne heure vers une sympathectomie pré-ganglionnaire *dorsale ou lombaire* suivant la localisation, qui donne des chances très appréciables de succès.

Dans les causalgies que faire ? Faut-il abandonner tout espoir ? Ne plus tenter les sympathectomies et envoyer directement ces malades aux neuro-chirurgiens pour des interventions médullaires ? Nous croyons que la sympathectomie peut être tentée car elle offre des espoirs de guérison, mais sans se faire trop d'illusions, et surtout sans faire trop de promesses au malade.

RÉSUMÉ

1) — 185 cas de traumatisme des nerfs périphériques ayant laissé des séquelles douloureuses sont analysés.

2) — *Les causalgies* et les *douleurs du membre fantôme* n'englobent que le quart des observations.

Les autres syndromes douloureux sont classés en :

— *névrome douloureux simple* avec des douleurs localisées en un point ou avec des irradiations purement descendantes ;

— *hyperesthésie douloureuse* dans le territoire sous-jacent à la lésion nerveuse ;

— *algie ascendante* remontant plus ou moins le long du trajet du nerf.

3) — La chirurgie ne doit être envisagée qu'après échec du traitement médical.

Les interventions locales (suture, neurolyse, neurotomie) ne donnent de bons résultats que dans les névromes douloureux simples.

Les autres syndromes douloureux relèvent de la sympathectomie préganglionnaire mais les résultats obtenus dans le traitement des causalgies sont décevants.

SUMMARY

1) — 185 patients having persistent pain after traumatic lesions of peripheral nerves are reviewed.

2) — Causalgia and painful phantom existed only in one forth of the cases.

The remaining pain syndromes are classified in :

— painful neuroma with pain on one spot or pain irradiating peripherically ;

— painful hyperesthesia where pain is located in the territory underlying the level of the lesion ;

— ascending algia where pain more or less follows the site of the nerve.

3) — Surgical intervention should not be performed unless medical treatment has been unsuccessfull.

Operation on the nerve lesion (suture, neurolysis, neurotomy) give good results only in painful neuroma.

Preganglionic sympathectomy gives better results in the remaining pain syndromes but in causalgia there is an important percentage of failures.

ZUSAMMENFASSUNG

1) — 185 Fälle von anhaltenden Schmerzen nach traumatischer Schädigung peripherer Nerven sind nachuntersucht worden

2) — Causalgie und schmerzvolle Phantomgliedmasse war nur in einem Viertel der Fälle vorhanden

Die anderen schmerzhaften Syndrome sind in der folgende Weise klassifiziert worden

Das schmerzhafte Neurom das durch punktformiger Schmerz oder durch peripherwärts ausstrahlender Schmerz gekennzeichnet ist

schmerzhafte Hyperästhesie am Orte der Nervenschädigung

— aufsteigende Schmerzhaftigkeit in der der Schmerz mehr oder weniger dem Nerven entlang lokalisiert sind

3) Chirurgische Behandlung sollte nur dann eingesetzst werden wenn medizinische Behandlung sich als erfolglos erwiesen hat

örtliche Eingriffe in den peripheren Nervenschadigungen (Sutur Neurolysis Neurotomie) geben gute resultate nur bei den einfachen schmerzvollen Neuromen

Die anderen schmerzhaften Syndrome müssen mittels praganglionaler Sympatectomie behandelt werden Bei der Causalgie sind die Ergebnisse jedoch schlecht

BIBLIOGRAPHIE

Barnes R Causalgia review of 48 cases Nerve injuries Committee of the Medical Research Council 1 150 185 London 1954

Bombart Séquelle douloureuse de lésures traumatic en nerfe peripherique Thèse Paris 1961

Mayfield F H et Devine J W Causalgia Surgery gynecology and obstetrics 80 631 635 1945

R Merle d'Aubigné et J Benassy La sympathectomie préganglionnaire dans le traitement des algies posttraumatiques des membres La semaine des hôpitaux de Paris 44 1492 1494 1948

R Merle d'Aubigné et J Benassy La sympathectomie préganglionnaire dans le traitement des moignons douloureux et des causalgie Academie de Chirurgie 1 50 63 1952

M Tiret Traitement des moignons douloureux et causalgies des membres par sympathectomie préganglionnaire Thèse Paris 1953

J I Ulmer et F H Mayfield Causalgia A study of 75 cases Surgery Gynecology and Obstetrics 83 789 796 1946

J C White W B Heroy et E M Goodman Causalgia following gunshot injuries of nerve Annal of surgery 128 2 161 183 1948

J C White et R H Smithwick The autonomic nervous system The Mac Millan Company New York 1952

SURVIVAL IN BONE SARCOMA

By

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INTRODUCTION

The sarcomas of bone have for many years been regarded as amongst the most lethal forms of malignant disease This is still true and the outlook in general remains grave But recent analyses of survival periods after ablation of the tumours by operation or irradiation have dispelled some of the extreme pessimism which has long surrounded this problem Much of our information comes from the United States of America where during the past generation large collections of documented material relating to bone tumours have been concentrated in a relatively few centres The standards of five and ten year survival periods have been used as in other forms of malignant disease (*Geschickter & Copeland* 1931 1949 *B L Coley et al* 1949 *Coventry & Dahlin* 1957)

PERSONAL MATERIAL

Classification My own fully documented collection of bone sarcomas covering the period 1920 to 1961 comprises 256 tumours

TABLE I

	Total	Operable Tumours
Osteogenic Sarcoma	151	[illegible]
Extra Periosteal Sarcoma	33	23
Ewing's Tumour	30	21
Malignant Giant Cell Tumour	5	4
Sarcoma in Abnormal Bone	31	24
	2 6	0

Number of five year survival 58 (21%)

The classification adopted in the above table is used for the purpose of introducing the broad clinical picture of this field of malignant disease. But for many years in both undergraduate and postgraduate teaching I have found it convenient to adopt a simple classification of primary malignant tumours of bone based on the recognition of the tumours as anatomical and clinical entities. In this two main categories of tumour are distinguished – the *extra osseous* tumours and the *intra-osseous tumours* (*Platt 1951*).

TABLE II

Extra Osseous Group	Osteogenic Sarcoma –	Sclerosing
		Osteolytic
	Ewing's tumour	Chondro sarcoma
	Extra periosteal sarcoma	
Intra Osseous Group	Chondro myxo sarcoma	
	Endosteal fibro sarcoma	
	Malignant giant cell tumour	
	Haemopoietic tumours	
	Adamantinoma	

It will be noted that I have retained the extra osseous chondro sarcoma tumours within the osteogenic sarcoma class. This is for convenience in clinical diagnosis. The intra osseous chondro sarcomas like other primary malignant intra-osseous tumours are relatively uncommon – in my series 11 out of 44 tumours of the malignant cartilaginous group.

Survival Periods

Osteogenic Sarcomas – 151 cases: Males 95, Females 56

Osteolytic type	
Chondromyxosarcoma type	
Sclerosing type	

In this group 30 patients have survived 5 years and over since eradication of the tumour with 15 of these surviving beyond the 10 year follow up period. In 121 operable tumours this represents an over all survival rate of 24 % (1) Of these thirty long survivors 15 are *chondromyxomas* 7 of whom lived beyond the ten year period with the longest survivor still alive seventeen years following a disarticulation at the shoulder joint (2) 12 are *osteolytic* sarcomas with 6 survivals over ten years and with the longest survivor alive and well twenty one years after a mid thigh amputation (Figs 1 2 and 3) (3) Three are *sclerosing sarcomas*



Fig 1
Male Age 11 Osteogenic Sarcoma Tibia Upper End (L) (Osteolytic type)

The mortality rate within the three year period (short survivals) following ablation of the tumour was a little over 50% in the chondro myxo sarcomas 70% in the osteolytic tumours and 90% in the sclerosing tumours These facts give us a crude picture of the relative malignancy of these three types of osteogenic sarcoma

Extra Periosteal Sarcomas 39 cases (parallel 79) {Females 25, Males 14}

In this group there are 11 five year survivors 9 of them alive over ten years from the date of removal of the tumour By contrast 12 patients died within the three year period with one of them surviving less than one year Thus this small series contained a high proportion of lethal tumours

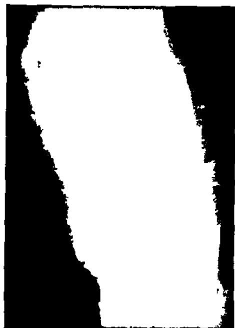


Fig 2
Same case Pre-Operative X ray *Histology* Spindle cell Sarcoma with numerous mitoses and some bone formation



Fig 3
Same case X ray of amputation specimen Patient alive and well 21 years after mid thigh amputation

Ewing's Tumours This type of bone sarcoma has long been regarded as the most deadly of the primary malignant tumours of bone although in 133 such tumours in the collection of *Geschickter & Copeland* (1949) there was a five year survival rate of 19 %. My own limited experience of this uncommon lesion illustrates the fallacies involved in the estimation of survival periods at any given time In 1950 out of 23 Ewing's tumours (16 operable) I could record no five year survivors But by 1961 in 30 cases there were now 8 five year survivors five of whom had lived over ten years! Nevertheless over two thirds of my patients had died within two years from the time of the ablation of the tumour The comment may be made that this series of Ewing's sarcomas could include tumours which in the opinion of some authorities would be regarded as reticulum cell sarcomas – tumours which are believed to offer a more favourable prognosis than the classical Ewing's sarcoma

Sarcoma in Abnormal Bones This group of 31 sarcomas includes 18 *fibroblastic sarcomas* arising in Paget's disease 2 such tumours in

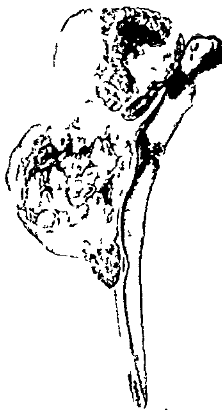


Fig 4
Male Age 48 Chondrosarcoma Scapula (L) Specimen after total excision of scapula Period of survival 9 years following operation Pulmonary metastases at the time of follow up

osteodystrophia fibrosa and *11 chondro-sarcomas* representing malignant "transformation" in *benign chondromas* of long standing. The Paget sarcomas which may have a multifocal origin are in general highly lethal although two of my patients survived for five and six years respectively. Of the two tumours arising in bones affected by osteodystrophia fibrosa one patient lived for six years and the other for nine years. This is perhaps not an unexpected behaviour pattern but the number of examples of this sequence of events is too few to justify any generalisations.

The advent of malignant change in a *benign osteochondroma* more

particular in tumours which have grown to large size has always presented a difficult diagnostic problem. As *Bradley Coley* (1960) has pointed out the histological picture is not always a reliable guide and he emphasises the need for early radical extirpation of all doubtful tumours, a procedure which I have long advocated (*Platt* 1931, 1951). Here again the outlook for survival should be at least as favourable as in the so-called primary chondromas. Five out of eleven patients in this very small series passed the five year period.

Malignant Giant Cell Tumours. In my very small series, 5 cases in all, 4 patients died within a year, and one survived for just over three years.

FACTORS IN PROGNOSIS

The broad picture of potential survival rates in the various categories of bone sarcoma presented by the analysis of my own material is in accordance with the findings of others who have investigated this problem in much larger collections of tumours. These facts cannot, however, be used without reservations in any attempt to predict the statistical chances of long or short survival in individual tumours. The problem is one of practical importance in the not uncommon tumours of the osteogenic sarcoma group. From time to time attempts have been made to assess the significance of factors which either singly or in combination might be concerned in determining lengths of survival – *Bradley Coley & J. J. Pool* (1940), *A. B. Ferguson* (1940), *MacDonald & Budd* (1943) and *Bradley Coley & C. C. Harrold* (1950). More recently the results of important studies have come from the Argentine – under the guidance of *Jose Valls* (*Mondolfo, Schajowicz & Derqui* 1960), from the Mayo Clinic (*Coventry & Dahlin* 1957, *Troup & Bickel* 1960) and in Great Britain from *Price* (1961). The many contributions to this problem over a long period by *Geschickter & Copeland* have also been invaluable.

Factors subjected to scrutiny as potentially significant have been age, sex, duration of symptoms before treatment, of the tumour site of origin, periodicity in tumour growth, histological grading and methods of treatment. It should be said at once that the findings of different observers in relation to the apparent role of many of these factors are conflicting.

Take for example the *age* groups in the osteogenic sarcomas. *Bradley Coley & Pool* (1940) found the prospects of long survival less favourable under the age of 10 and over the age of 40. In my own series b

contrast a substantial proportion of the short survivals fall into the age period 10–20 whereas the majority of the three year and over survivals (which include the long survivals of five years and over) have been found in the 20–30 age period or in the over 40 age period From the records of the General Register Office (Great Britain) during the period 1951–1953 the age period of maximum mortality in primary malignant bone tumours in the limbs was 15–19 the mortality rate fell between the ages of 20–34 but rose from 40 onwards due to the incidence of Paget s Sarcoma

In 353 osteogenic sarcoma patients whose fate was known analysed by *Coventry & Dahlin* there was an over all 5 year survival rate of approximately 19 3 % and a 10 year survival rate of 15 3 % in patients under 30 21 2 % 30 years and over 14 3 % The 10 year survival rate in these two age groups was 17 7 % and 8 1 % respectively

Sex incidence has no relevance to prognosis As regards the *sites* of tumours *Coley & Pool* found that in tumours in the distal parts of the limbs there were more five year survivals than in the upper end of the femur *Coventry & Dahlin* (loc cit) found that in osteogenic sarcomas below the upper end of the femur the long survival rates were 28 % (5 year survivals) and 17 6 % (10 year survivals) In osteogenic sarcomas involving the upper end of the tibia there was a substantially larger 5 year survival rate (34 6 %) It is clear however that this factor cannot be considered in isolation from the question of the ease of accessibility of the tumour to operative attack Similarly periods of *duration of symptoms* do not necessarily give an accurate estimate of the age of these tumours It would be natural to expect that the prompt ablation of an osteogenic sarcoma discovered by accident in its earliest stage might guarantee a longer survival than a rapidly growing tumour discovered at a time when its clinical features were unmistakeable But even such a sweeping generalisation could prove to be fallacious

In the course of the analysis of survival rates by *A B Ferguson* (loc cit) by *Bradley Coley & Pool* (loc cit) and by *MacDonald & Budd* (loc cit) evidence emerged which suggested that some malignant bone tumours exhibited alternate periods of activity and regression This led to the conclusion that a better prognosis would follow a policy of deliberate delay in extirpating the tumour after the diagnosis had been established The majority of surgeons with a large experience in this field have not been convinced that such a policy is justifiable

We are thus left with two factors which merit more detailed con

particular in tumours which have grown to large size has always presented a difficult diagnostic problem. As *Bradley Coley* (1960) has pointed out the histological picture is not always a reliable guide and he emphasises the need for early radical extirpation of all doubtful tumours, a procedure which I have long advocated (*Platt* 1935, 1951). Here again the outlook for survival should be at least as favourable as in the so-called primary chondromas. Five out of eleven patients in this very small series passed the five year period.

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Factors subjected to scrutiny as potentially significant have been age, sex, duration of symptoms before treatment of the tumour, site of origin, periodicity in tumour growth, histological grading and methods of treatment. It should be said at once that the findings of different observers in relation to the apparent role of many of these factors are conflicting.

Take for example the *age* groups in the osteogenic sarcomas. *Bradley Coley & Pool* (1940) found the prospects of long survival less favourable under the age of 10 and over the age of 40. In my own series by

practicable and this more conservative technique has been increasingly used in recent years Where the gap following resection can be filled by a prosthesis (plastic or metal) as in the upper end of the humerus or upper end of the femur a useful limb can be preserved In the knee region – a favourable site for bone sarcoma – wide resection demands the use of massive bone grafts in order to secure an arthrodesis – a procedure which necessitates a long period of immobilisation of the operation area Experience has shown that failure to achieve solid fusion is by no means uncommon Similarly in tumours of the shafts *of long bones* which embrace the *Ewing's tumours* wide resection involves bridging the gap by a substantial graft In certain uncommon sites for example the ulna or fibula the gap can be left unfilled without any appreciable loss of function in the limb

Tumours of the *scapula* offer almost ideal anatomical conditions for local resection with the preservation of a useful upper limb even after total excision of the shoulder blade In my own series of nine scapular tumours there are three long survivors – (1) an osteolytic sarcoma treated by excision of the lower third of the bone (15 year survival) (2) *a chondrosarcoma surviving 9 years after total excision and (3)* (Fig 4) an extraperiosteal sarcoma surviving 16 years after total excision

I have no doubt however from my own experience that resection in tumours of the long bones carries a definite risk of local recurrence both in the highly malignant and less malignant types of tumour

This liability has been recognised by others (*Mondolfo et al 1960*) The practice of ablating primary malignant tumours of bone by radical surgical measures (disarticulation amputation or local resection) still holds the allegiance of the majority of surgeons who are continuously occupied in the diagnosis and treatment of these tumours

If amputation be accepted as the surgical method of choice in tumours where for anatomical reasons local resection is impracticable the question arises whether or not the level of the amputation has any *influence* on the length of survival *It* was *Joseph Bloodgood* a pioneer in the study of bone tumours who long ago taught that amputation at levels well above the limit of the tumours is all that is required

From the Mayo Clinic (*Troup & Bickel* 1960) come the results in terms of survival in 264 patients treated by hindquarter amputation disarticulation of the hip and forequarter amputation

In this series the level of ablation per se would seem to have no specific determining influence on survival rates

The role of irradiation in the treatment of primary malignant tumours of bone has been much debated for more than a quarter of a century. When it became apparent that the Ewing's tumour was highly radio-sensitive, irradiation was advocated as the therapy of first choice in tumours whether accessible or inaccessible to operative attack. Nevertheless, when local recurrence followed a period of apparent obliteration of the tumour – a not uncommon event – resection or amputation had now to be carried out. For this reason many surgeons have always preferred to treat Ewing's tumours by radical surgical measures without delay. In the majority of the centres in the United States to which large numbers of bone tumours began to gravitate, irradiation became reserved for inoperable tumours, or as a preliminary to surgical ablation. At the New York Memorial Hospital pre-operative irradiation was given a prolonged trial in tumours known to be radio-resistant, e.g. osteogenic sarcomas and extra-periosteal sarcomas, but this procedure was ultimately *discarded in common* with the use of Coley's toxins (*Bradley Coley & Harrold* 1950).

Striking advances in radiotherapeutic technique have been made since those earlier years, and it is now claimed that the question of relative radio-sensitivity is no longer all-important. Thus in 9 patients with osteogenic sarcoma treated by heavy radiation (*Tudway* 1961) five survived for 3–14 years. The conclusions drawn from these observations, however, were that the method should be used in the upper limb tumours only.

But even in the upper limb the arguments in favour of abandoning surgical ablation of the tumour will carry *little weight* where conservative resections are feasible. Indeed, in extensive tumours of the shoulder region a more radical resection technique is available as a means of avoiding forequarter amputation. This consists of removal of the scapula, excision of the clavicle (partial or complete), the upper end of the humerus, with the sourrounding soft tissues. This type of resection of the shoulder girdle was apparently first practised over fifty years ago in Russia, and has been called the Tikhor-Linberg Resection (*Pack & Crampton* 1961).

In my judgement the case for the substitution of irradiation for surgical therapy as the first choice in operable *tumours in* both the osteogenic sarcomas and Ewing's tumours remains unproven. *Is there* a place for a preliminary destruction of the tumour to be followed by surgical extirpation (*Cade* 1955)? I can find no convincing evidence that much longer survival periods follow the adoption of this

plan of action This being so I come back to the human and social aspects of the problem of the choice of treatment – to me the disturbing situation by any deliberate policy of delay once a diagnosis has been established Following irradiation the chances of local recurrence or reactivation of the tumour cannot be ignored In such a sequence of events as I know from my own experience the surgeon is confronted at a later stage by the necessity of performing a more extensive local resection than would have been required at an earlier stage or he may be compelled to ampute or disarticulate a limb which could have been preserved After a long experience in this field of malignant disease my attitude towards the treatment of operable primary malignant tumours of bone remains unchanged for me the attacking policy is "once for all" The surgical removal of these tumours no matter how radical the technique may be is in the last analysis an act of mercy Long or short survivals depend on others factors – some known others unknown In the latter category lies the mystery of the existence in some individuals of an immunity factor which calls a halt to the metastasising sarcoma cells Assuming that there has been no mistake in diagnosis how else can we explain on the one hand very short survivals and on the other survivals of over twenty years in tumours belonging to the highly lethal categories?

SUMMARY

(1) In the writer's fully documented collection of 256 bone "sarcomas" the overall five year survival rate was 21 %

(2) In 121 operable tumours of the *osteogenic sarcoma* group the overall survival rate was 21 % In 30 long survivors (a) 15 were tumours of the *chondro-sarcoma* type with 7 patients surviving over 10 years (b) 12 were osteolytic sarcomas with 6 surviving over 10 years and (c) 3 only belonged to the sclerosing sarcoma type

(3) In 39 *extra periosteal sarcomas* there were 11 five year survivals (9 living over the 10 year period) but this small series contained a high proportion of lethal tumours

(4) In 30 *Ewing's sarcomas* there were 8 five year survivals with [illegible] patients living beyond the 10 year period

(5) In 31 "*sarcoma*" *arising in abnormal bones* a clinical group dominated by Paget's disease the Paget's sarcomas were highly lethal although 2 patients out of 18 survived over 5 years In the "secondary" chondro-sarcomas (malignant transformation in be

nign osteochondromas) and the few sarcomas in osteodystrophia fibrosa the prognosis was more favourable

(6) The *malignant giant cell tumours* (5 cases only in the collection) were all highly lethal

(7) The broad picture of relative malignancy in the various categories in bone sarcoma is well established A scrutiny of factors which might possibly be significant in determining prognosis in any given tumour affords little evidence which can be regarded as significant More exact prediction may come from a detailed study of cytological grading

(8) In the treatment of bone sarcomas the writer is a convinced advocate of early extirpation of the tumours by surgical methods (resection or amputation) In the last analysis however the fate of the patient i e the early or remote appearance of pulmonary metastases does not depend on the method of treatment Survival rates were most probably related to the existence or non existence of an immunity factor which inhibits the spread of metastasis in sarcoma cells

RESUME

(1) Dans le collection de 256 «sarcomes» osseux entierement documentee par l auteur le pourcentage de survie pour une periode de cinq ans a eté de 21 %

(2) Dans 121 tumeurs opérables du groupe des *sarcomes osteogeniques* le pourcentage de survie a ête dans l ensemble de 24 % Dans 30 cas de longue survie (a) 15 étaient des tumeurs du type *chondrosarcome* avec 7 malades ayant survecu pendant 10 ans et (c) 3 seulement appartenaient au type du sarcome sclerosant

(3) Dans 39 *sarcomas extra periosteal* il y eut 11 cas de survie de 5 ans (9 ayant vecu pendant la periode de 10 ans) mais il y avait dans cette petite serie un pourcentage eleve de tumeurs letales

(4) Dans 30 *sarcomes Ewing* il y eut chez 8 malades une survie de cinq ans avec 5 malades au dela de la periode de 10 ans

(5) Dans 31 *«sarcomes» survenus dans des os anormaux* – un groupe clinique domine par la maladie de Paget le sarcome de Paget entraina une letalite elevee seulement 2 malades sur 18 ayant survecu pendant 5 ans Dans les chondrosarcomes «secondaires» (transformation maligne d osteochondromes bénins) et les rares sarcomes de fibrose osteodystrophique le prognostic fut plus favorable

(6) Les *tumeurs malignes a cellules geantes* (5 cas seulement de la serie) ont donne un pourcentage elevé de letalite

(7) Le tableau de la malignite relative des differentes categories de sarcomes osseux est bien etabli. Une etude des facteurs qui ont peut etre une importance decisive pour le pronostic de chaque categorie de tumeur ne semble pas apporter de donnees decisives. Des previsions plus exactes peuvent decouler d une etude detaillee du degre cytologique

(8) Dans le traitement des sarcomes osseux l auteur est partisan convaincu d une extirpation precoce des tumeurs par intervention chirurgicale (resection ou amputation). L analyse du sort du malade montre que l apparition precoce ou tardive de metastases pulmonaires ne depend pas de la methode de traitement. Le pourcentage de survie est plus probablement lie a un facteur d immunite qui empeche la propagation des cellules metastatiques du sarcome

ZUSAMMENFASSUNG

(1) In der vom Verfasser authentisch belegten Sammlung von 256 Knochensarkomen war die gesamte Uberlebungszahl nach funf Jahren 21 %

(2) Bei 121 operablen Tumoren der *osteogenetischen* Sarkomgruppe war die Gesamtzahl der Uberlebenden 24 %. Bei 30 lang Uberlebenden (a) handelt es sich in 15 um Tumoren der *Chondrosarkom* Type, von denen 7 Patienten langer als 10 Jahre lebten (b) 12 waren osteolytische Sarkome, davon 6 mehr als 10 Jahre uber lebend und (c) nur 3 gehorten zur sklerosierenden Sarkomtype

(3) Von 39 *extraperiostalen Sarkomen* uberlebten 11 die Fünfjahrsperiode (9 leben noch nach 10 Jahren). Aber diese kleine Reihenfolge enthalt eine hohe Anzahl von totlichen Tumoren

(4) Von 30 *Ewings Sarkomen* uberlebten 8 die Funfjahrsperiode, davon lebten 5 Patienten uber 10 Jahre

(5) Bei 31 *Sarkomen die von abnormen Knochen ausgingen* – einer klinischen Gruppe die von der Paget Erkrankung beherrscht wird – waren die Paget Sarkome ausserst lethal, obwohl von einer Gruppe von 18 Patienten 2 mehr als 5 Jahre uberlebten. Bei den sekundaren Chondrosarkomen (maligne Entartung bei gutartigen Osteochondromen) und bei den wenigen Sarkomen in Fallen von Osteodystrophia fibrosa war die Prognose gunstiger

(6) *Die bösartigen Riesenzellengeschwülste* (nur 5 Fälle in dieser Sammlung) waren alle äusserst lethal.

(7) Das Bild der verhältnismässigen Bösartigkeit der verschiedenen Kategorien von Knochensarkom ist wohl bekannt. Eine Prüfung von Faktoren, die möglicherweise bezeichnend für die Bestimmung der Prognose eines gegebenen Tumors sein könnten, liefert wenige Beweise, die als charakteristisch angesehen werden können. Eine *genauere Voraussage kann vielleicht durch eingehendes Studium* der cytologischen Abstufungen möglich gemacht werden.

(8) In der Behandlung der Knochensarkome ist der Verfasser ein überzeugter Fürsprecher der frühzeitigen Exstirpation des Tumors mit chirurgischen Methoden (Resektion oder Amputation). In der Endanalyse jedoch hängt das Geschick des Patienten, d. h. das Früh- oder Spätauftreten von Lungenmetastasen, nicht von der Behandlungsart ab. Die Überlebungszahl steht wahrscheinlich in Beziehung zu einem vorhandenen oder nicht vorhandenen Immunitätsfaktor, der die Ausbreitung von metastasierenden Sarkomzellen verhindert.

REFERENCES

Cade, Stanford. Osteogenic Sarcoma. Jnl. Royal Coll. Surg. Edinburgh, *1*, 79, 1955.
Coley, B. L. & Higinbotham, N. L. Ann. Surg., *117*, 1114, 1940.
Coley, B. L. Neoplasms of Bone. Hoeber. New York. 1949.
Coley, B. L. & Harrold, C. C. Jnl. Bone & Joint Surg., 32, 4, 307, 1950.
Coventry, M. B. & Dahlin, D. C. Jnl. Bone & Joint Surg., 39, 4, 741–757, 1957.
Dahlin, Coventry & Scanlon. Jnl. Bone & Jt. Surg., 43–4, 2, 1961.
Ferguson, A. B. Jnl. Bone & Jt. Surg., 22, 92, 1940.
Geschickter & Copeland. Tumours of Bone. 1st Edit. Lippincott. Philadelphia. 1931.
Geschickter & Copeland. Tumours of Bone. 3rd. Edit. Lippincott. Philadelphia. 1949.
MacDonald, Ian & Budd, J. W. Surg. Gynec. Obstet., *77*, 413, 1943.
Mondolfo, S., Schajowicz, F. & Derqui, J. C. Revista de Orthopedia y Traumat. Ibero-Latino Americana. Vol. V. No. 2. Julio, 1960.
Pack, George T. & Crampton, Ray S. The Tickor Linberg Resection of the Shoulder Girdle. Clinical Orthopaedics No. 19. Pitman Medical Publishing Co. Ltd., London. J. B. Lippincott & Co. Philadelphia & Montreal. 1961.
Platt, Harry. The Lady Jones Lecture on Malignant Tumours of Bone. Liverpool Medico-Chirurgical Jnl., XLIII, 42, 1935.
Platt, Harry. Diagnosis & Prognosis in Sarcomas of Bone. Annals Royal College of Surgeons of England, *8*, 87–114, 1951.
Price, C. H. G. Jnl. Bone & Jt. Surgery, 43 *B*, 2, 1961.
Registrar General of England and Wales. Statistical Review of England and Wales. 1953.
Trout, James B. & Bickel, William H. Jnl. Bone & Jt. Surgery, 59, 4, 2, 1960.
Tudway, Robert C. Jnl. Bone & Joint Surgery, 43 *B*, 1, 1961.

FROM THE ORTHOPAEDIC DEPARTMENT, KAROLINSKA INSTITUTET, STOCKHOLM (HEAD: PROF. S. FRIBERG)

CYSTIC LESIONS OF BONE RESEMBLING GIANT CELL TUMORS

By

T. HIERTONN & F. SALEN

Multinuclear cells are found in the stroma of a number of different types of cysts and cystlike processes within the skeleton. Because of the occurrence of these giant cells, tumor forms embracing widely differing anatomical and clinical processes often were collected under the general term of giant cell tumors. During the past 20 years it has been possible by comparative histological, clinical and roentgenological studies, notably by American pathologists (*Jaffe*, *Lichtenstein*), to divide this previously heterogeneous group of giant cell tumors into distinct subgroups of tumors or tumorlike processes.

The following pathological conditions have been separated from the heterogeneous group of giant cell tumors:

- true giant cell tumor
- solitary bone cyst
- aneurysmal bone cyst
- chondroblastoma
- non-ossifying fibroma
- (certain cystic changes in the jaw bones.)

During recent years an increasing number of bone tumors have come for treatment at the orthopaedic clinic of the Karolinska Institutet and a closer collaboration has developed with Radiumhemmet and the institutions for tumor pathology and general pathology. A short description seems justified of some of the cyst like changes which usually cause diagnostic difficulties. For more detailed descriptions the reader is referred to the monographs by *Dahlin* 1957 and *Jaffe* 1958.

The true giant cell tumor commonly occurs between 20 and 40 years



Fig. 1.

Roentgenogram of a giant cell tumor in the upper end of a tibia. Note the pure lytic lesion eccentrically located. No periosteal reaction. Female 5a of age.

of age. The sites of predilection are the inferior femoral and superior tibial epiphyses together with the inferior radial epiphysis. The clinical symptoms consist of the gradual onset of pain, swelling and eventually limitation of movement in the adjacent joint. X-ray shows a fairly large, well delineated osteolytic process eccentrically placed in an epiphysis (see fig. 1). One can often see that it has been a relatively fast progression. Periosteal reaction is lacking. Sclerosing new bone formation occurs only in cases treated by radiation. The macroscopic appearance of the tumor varies. Sometimes one sees a greyishwhite rather dense tumor tissue, at other times the colour is reddish or brown and the consistency soft.

Histologically there is a stroma of different forms of fibroblasts, a network of blood vessels, collagen fibrils and multinuclear cells. The histological picture often varies in different tumors and even in different parts of the same tumor, which can complicate the histological differential diagnosis.

From a prognostic and therapeutic point of view it is of the greatest importance in an individual case to be able to differentiate between the



Fig ?
Roentgenogram of a solitary bone cyst
Bo 7 year of a

true giant cell tumor and the other cyst like changes. A giant cell tumor although benign at first can in certain cases undergo a malignant transformation and metastasize to the lungs.

The solitary bone cyst usually is discovered in childhood often by a fracture through the cyst in association with trauma. The site of predilection is the superior humeral diaphysis. Solitary bone cysts occur even in the superior and inferior tibial and femoral diaphyses and in the superior fibular diaphysis. There is a widening of the shaft and a thinning of the cortex. (See fig. 2.) A callus formation during healing of fractures through the original cyst can produce a multilocular appearance of the cyst on the X ray film. At exploration the cysts are usually empty or contain only a little fibrinous slime or straw coloured fluid. Fresh bleeding can appear however in association with fractures. The material obtained by curettage of the cyst wall is usually of small amount and uncharacteristic appearance. If bleeding has occurred into the cyst an organized hematoma may be encountered. Histologically

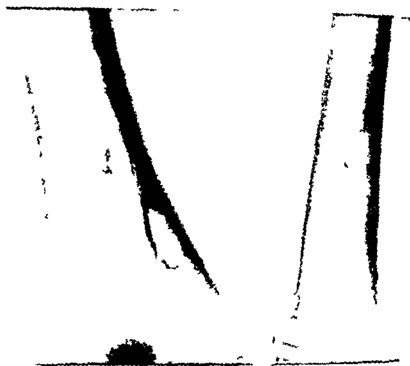


Fig 3
Röntgenograms of a non ossifying fibroma in the femur—Boy 6 years of age

the cyst walls consist of a very thin layer of fibroblasts overlaid by fibrin and even blood pigment phagocytes and sometimes multinuclear cells

The non ossifying fibroma usually occurs in adolescence up to the age of 20 years The site of predilection is the long bones of the lower limbs with localization in the ends of the diaphysis The clinical findings are unspecific Local tenderness is often present Usually the changes are discovered incidentally on X ray examinations for other reasons In some cases there seems to be a certain connection between trauma and the onset of symptoms With enlargement of the lesion spontaneous fractures can occur

Radiologically one observes a subcortically placed conglomeration of bubble formed rarefaction which is surrounded by a sclerotic zone (see fig 3) Small fibrous cortical bone defects are common in children and are not considered as tumors In certain cases these cortical bone defects can enlarge into the medullary cavity and thus assume the character of a non ossifying fibroma The fibroma can in addition grow towards the cortex which is thus thinned and pushed out into the surround-

soft parts Microscopically the fibroma is often brown or yellow coloured with a rather dense consistency The bone tissue is sclerotic around the fibroma The histological picture has certain similarities to giant cell tumors The stroma consists of spindle shaped cells and often contains lipophages and multinuclear cells The characteristic features are 1) The patients are usually under 20 years of age 2) The change is localized to the diaphysis not the epiphysis 3) The condition is benign there is a certain tendency to spontaneous healing Recurrence seldom occurs after a surgical curettage

The following is a typical case Case 1 B h A boy of 7 years of age treated elsewhere in 1954 for fracture through the lower part of the right femur shaft developed a cystic lesion in the fracture region After curettage of the cyst and packing with autologous bone chips the pathological report showed Giant cell tumor

The fracture healed He returned to the hospital in his home province for regular half yearly control He began to have aching above the right knee at the age of 13 In October 1960 a new cyst formation was observed in the right femur somewhat distal to the previous pathological region Uncertainty of the diagnosis the highly varying opinions which the parents received together with uncertainty regarding the plan of continued treatment led to his referral to the orthopaedic clinic

Preliminary assessment The age of the patient the localization and the roentgen appearance indicated non osteogenic fibroma (Fig 3)

Bloodcalcium normal

Because of the present symptoms and the previous histological interpretation of giant cell tumor a second curettage was performed The contents of the cystic lesion were sparse and of unspecific macroscopic appearance The preliminary histological diagnosis was Fibromatous giant cell tumor Because of the clinical and roentgenological picture the histological interpretation was reviewed and the final diagnosis accordingly was revised to a non ossifying fibroma

Benign chondroblastoma This has previously been described as calcifying giant cell tumor or chondromatous giant cell tumor It occurs in elder children and young adults rarely over the age of 20 years The usual sites are the femoral and tibial epiphyses around the knee joint and the upper humeral epiphysis The symptoms are insidious with slight pain on movement swelling and gradually a reduced range of movement in the adjacent joint X ray shows a rounded osteolytic process which can reach a diameter up to 5 6 cm Larger or smaller calcifications are generally found within the osteolytic region and this gives the lesion a mottled appearance (fig 4) There is the same tendency to an eccentric position in the epiphysis as with the giant cell tumor but not so outstanding and furthermore the latter is very rarely seen under 20 years of age The differential diagnosis usually includes giant cell tumor or a malignant tumor such as chondrosarcoma or osteogenic



Fig. 3.
Roentgenograms of a chondroblastoma in the epiphysis of a humerus. Note small calcifications indicated by arrows.

sarcoma; sometimes the lesion is taken for an infectious process. Macroscopically the tumor is bluish grey, yellow or brownish red and the consistency moderately firm. The histological picture is characterized by chondroblasts, the appearance of calcification and numerous areas of necrosis. These tumors are often misinterpreted because of the appearance of multinuclear cells. The prognosis is however good and malignant change is unknown.

Case 2. E. S. A girl of 15 years with pain and reduction of movement in the right humeral scapular joint, autumn 1961. The X-rays showed a localized cyst formation in the head of the humerus. The patient was treated in another hospital with short wave X-ray. Control Febr. 1962 showed progression. Needle biopsy: Unspecific cells of uncertain origin. Radiation therapy was started. The pain however increased. This led to the patient being referred to the orthopaedic clinic in March 196…

Preoperative assessment: Benign chondroblastoma. —Biopsy and curettage. The large cavity in the head of the humerus contained a bluish grey firm tissue. Microscopic pathology: Benign chondroblastoma (Codman tumor). After this operation healing was uneventful. The prognosis was judged as favourable. The mobility of the humero-scapular joint improved.

Aneurysmal bone cyst. This peculiar skeletal change occurs in children and adolescents, seldom in patients over 20 years of age. The commonest localizations are the ends of the diaphyses of the long bones and vertebral column. The symptoms depend on the site. In the back stiffness, swelling, eventually root pain may occur. In the long bones there will be local swelling, tenderness, minor ache and limitation of move-



Fig

Roentgenogram of an aneurysmal bone cyst in a humerus. Note the ballooned out area laterally. Girl 17 years of age

ment in the adjacent joint. In most cases the roentgenographic findings are characteristic. The cyst formation grows eccentrically and is surrounded by an eggshell like periosteal calcification. The similarity to an aneurysm has given rise to the name. The above mentioned eccentric growth serves to differentiate the aneurysmal bone cyst from a solitary bone cyst which grows concentrically. The differential diagnosis is not difficult in the typical cases with the eccentric protrusion of the cyst formation and the periosteal calcification.

A typical case is described below.

Case 3 P B. Previously healthy girl of 17 years of age. 1959 minor contusion of the right elbow region followed by local tenderness and limitation of movement. X-ray examination: Walnut sized tumor protruding laterally in the distal part of the humerus. Biopsy, Sparanten! Pathological diagnosis: "A picture resembling giant cell tumor. Probably congenital bone cyst."—Immobilization in plaster one month. A following roentgenogram showed progression. Operation with curettage revealed a cyst with profuse bleeding. Pathology report: Aneurysmal bone cyst.

Due to the differing opinions of the histological diagnosis the patient was referred to the Orthopaedic Clinic 7/1 1960. Roentgen (Fig. 5) showed a large ballooned out cystic lesion of the lower end of the humerus.—Operation: *Curettage of bone cyst right humerus + packing with autogenous cancellous bone-chips from the iliac crest*

The walls of the cyst were paper thin. Perforation into the soft tissues was present in several places. There was found blood under slight pressure within the cyst and brownish red soft slime covering the walls. The pathology report confirmed the diagnosis of an aneurysmal bone cyst.

DISCUSSION

From a practical view point it is of great importance that the orthopaedist and the roentgenologist who care for skeletal tumors and skeletal diseases also have a knowledge of the pathologic characteristics of the conditions. It is also clear that the histological picture alone is not always sufficient for the exact diagnosis. It frequently occurs that the pathologist, in order to reach a definite diagnosis, is in need of clinical and roentgenological information in the particular case. Certain of these cyst like lesions, for example the non ossifying fibroma, have a histological picture which closely resembles the genuin giant cell tumor. The combined clinical, roentgenological and histological analysis is therefore of greatest value in determining the diagnosis, deciding on treatment and assessing the prognosis. The cyst like changes in the skeleton which have been described are examples of such lesions which in the older textbooks were gathered together in a large heterogenous group, the so-called giant cell tumors, but where modern diagnosis allows more specific differentiation. These conditions are not in general sufficiently well recognized and because skeletal tumors are relatively seldom seen, a certain centralization is desirable to institutions where the time, interest and combined resources are available.

SUMMARY

For the diagnosis of cystic lesions of bone resembling giant cell tumors a clinical, roentgenological and pathological cooperation is emphasized. — A short description is given of the true giant cell tumor, the solitary bone cyst, the aneurysmal bone cyst, the benign chondroblastoma and the non ossifying fibroma, which all may be confused with giant cell tumor.

RESUME

Il est recommande une collaboration clinique, radiologique et pathologique pour etablir le diagnostic de lesions kystiques osseuses ressemblant a des tumeurs de cellules geantes. — Une courte description est donnee de la veritable tumeur de cellules geantes, du kyste osseux soli-

taire du kyste osseux anevrysmal du chondroblastome benin et du fibrome non ossifie qui peuvent tous etre confondus avec les tumeurs de cellules geantes

ZUSAMMENFASSUNG

Zur Diagnose von cystischen Lesionen des Knochens die Riesen zellengeschwülsten ähneln wird die Notwendigkeit der klinischen röntgenologischen und pathologischen Zusammenarbeit hervorgehoben – Eine kurze Beschreibung der echten Riesenzellengeschwulst der solitären Knochencyste der Aneurysma Knochencyste des gutartigen Chondroblastoms und des nicht knochenbildenden Fibroms die alle mit Riesenzellengeschwulsten verwechselt werden konnen wird gegeben

REFERENCES

Dahlin D Bone Tumor Ch Thomas Publ Springfield 19 7

Jaffe H Tumors and Tumorous Conditions of the Bones and Joints Lea & Febiger 1958

Lichtenstein L Bone Tumors The Mosby Co St Louis 1959

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For the diagnosis of cystic lesions of bone resembling giant cell tumors a clinical, roentgenological and pathological cooperation is emphasized. — A short description is given of the true giant cell tumor, the solitary bone cyst, the aneurysmal bone cyst, the benign chondroblastoma and the non ossifying fibroma, which all may be confused with giant cell tumor.

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Il est recommandé une collaboration clinique, radiologique et pathologique pour établir le diagnostic de lésions kystiques osseuses ressemblant à des tumeurs de cellules géantes. — Une courte description est donnée de la véritable tumeur de cellules géantes, du kyste osseux soli

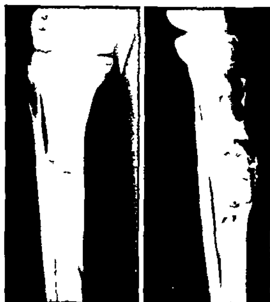


Fig. 1
X-ray 2 months before operation 3.4.1948

was chiselled and scraped out and the large defect was filled with bone chips from the bone bank. Quite a large subcutaneous oedema was found within the area of the tumour. The periosteum was considerably thickened. It could, however, be easily freed from the tibia. In some places perforations in the corticalis could be seen, through which the periosteum proliferated towards the medullary cavity. On the other hand no point could be seen where the tumour grew out into the soft tissue. At the places where the changes were largest the corticalis was almost as thin as paper and after the tumour masses were removed there was not much left of the corticalis in parts. Proximally the tumour extended subchondrally towards the articular surface of the tibia. Distally it reached a point 13 cms. above the ankle joint. Apart from the spontaneous fracture for which the patient was first admitted to the clinic, a further fracture was sustained during the operation.

The tumour showed everywhere the picture typical of chondroma, i.e. a brittle, almost amorphously granular, easily crumbling mass of a blue-white colour. Typically it grew out into the bone in rounded cavities large and small in size, everywhere, however, the tumour was well defined. The patho-anatomic diagnosis showed the typical picture

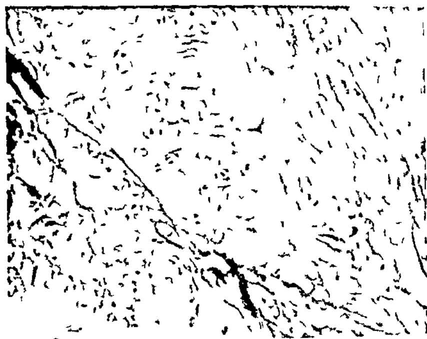


Fig. 2
Microphotograph of the tumour (× 60)

of a chondroma (fig. 2). The aftercourse was on the whole uneventful. It was not until 4½ month after the operation that the bone was so stable that we ventured to begin movement therapy of knee and ankle joints and the patient was allowed to begin weightbearing 6 months after the operation.

When it was decided to carry out an evacuation of the tumour we planned to follow the course of healing with isotopes and as stated above we chose Sr^{85}. From published research (*Bauer* and others) it is known that radio activity increases for years after a skeletal injury e.g. after a fracture. In the present case however the situation was somewhat different since heterologous transplants had been used and we considered that this point was of some interest. With the Sr^{85} technique there should be some opportunity of following the processes of new bone formation and bone regeneration during the period of healing. In order to be able to follow the course of healing from all aspects and to be able to verify any possible recurrence it should also be possible to carry out histological examinations in the bone tissue apart from the current radiological examinations. Therefore on the 23.1.1959 (about 9 months after the 1st operation) an exploration of the proxi-

mal part of the operation area was made It was then found that a few of the transplants implanted in the first operation were loose but no macroscopic tissue reaction could be found around them The great majority of the transplants had healed well but could be easily distinguished from the patient s own corticalis owing to the rough and uneven structure Non united bone chips were removed Samples were taken from the parts where the bone chips had united and also from parts of the original corticalis All samples were sent for histological examination and for measurement of radio activity

The loose non united transplants proved for the most part to consist of necrotic bone where the cell nuclei had disappeared whereas the united transplants as expected consisted of vital bone Accordingly the same degree of radioactivity was also obtained for the united transplants as for parts from the original tibia of the patient while the non united transplants did not show more activity than that given by background radiation in spite of the fact that they lay in a radioctively very contaminated area

On tomography on the 28 5 1959 that is almost 14 months after the 1st operation (fig 3) some areas of rarefaction had been found in the bone structure in the lower part of the tibia On counting moreover an increased activity had been found within these areas which indicated an active process so that the recurrence diagnosis was considered to be established *On the 8 6 1959 a fresh exploration was carried out therefore* this time comprising the distal half of the tibia No macroscopic signs of recurrence were found however at the site of the radiological changes and the histological examination showed vital bone without any suspicion of chondroma characteristics As in the preceding operation samples were taken from the united transplants and from the original corticalis of the patient The histological picture of the former showed vital bone and counting of the radioactivity showed the same range as for the tibia in other respects

TABLE 1

Time for injection of Sr 85		*Sr in µC*
1958	1/4	3 5
	16 4	32 5
	8 9	3
1959	3 6	29
	29/12	28 5
1960	15/7	30
1962	16 1	30



Fig. 3
X-ray 1 year after the operation

Otherwise it can only be added that the patient has worked since the winter of 1959 to full capacity as a farmer. He carries out very strenuous and demanding tasks and never uses any kind of support when he walks. He has a good mobility in both knee and ankle joints.

Table 1 gives the dates of the Sr injections and the amounts of radioactive Sr which were injected.

TABLE –
Biological half life
Days

Counting points	M[illegible] [illegible] 1958	Oct. 1958 Jan. 1959
		53
	33	53 5
1	33 40	30
2	28 29	
3		

In the tests with Sr the method described by *Bauer & Wendeberg* was applied. The counting sites on the diseased leg and healthy leg were marked and the counting was carried out under identical test



Fig 4
X ray 16 1 1962 almost 4 years after the operation

conditions on each occasion The results appear in fig 5 In this the counting values from the Sr injection in January 1962 have also been included i e almost 4 years after the first operation

From the course of the curves the *biological* half life was calculated both during the period May August 1958 and the period October 1958 January 1959 The approximate values are to be found in Table 2

The values of the biological half life are an expression of the speed with which the radioactivity disappears from each counting point They have no general significance but they do allow a comparison to be made between various periods of time for precisely that point at which they were counted In this patient therefore the biological half lives are throughout shorter during the first four months after the operation than during the period 6 9 months after the operation This of course is a way of saying that bone tissue regeneration proceeds more quickly during the former period than during the latter And this is also indeed what one should expect from a biological point of view

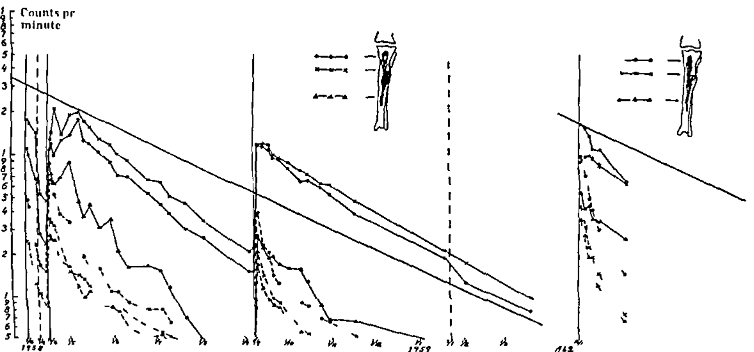


Fig. 5

The curve shows the results of counting with Sr^{85}. The continuous curves [illegible] the straight lines show the physical half life of Sr^{85}. The injection [illegible] of Sr^{85} are [illegible] straight line show the physical half life of [illegible]. The injection dates of [illegible] are [illegible] in Table 1

A test with Sr^{85} 3¾ years after the operation when there is still considerably higher quantity of Sr^{85} present in the operated leg than in the healthy leg shows that the increased speed of bone renewal still exists on the side treated even after this quite long period

The previously discussed results in the text of radioactivity in united chips and in loose lying chips should be give the interpretation that the united chips have undergone regeneration and passed into bone specific to the body

SUMMARY

A case of enchondroma tibia in a man aged 66 An operation was performed in which the tumour was scraped out and bone chips from the bone bank were implanted The course of the healing was followed by counting the radioactivity following injection of Sr^{85} 4 years after the operation the diseased leg still shows increased activity The biological half life was greatest during the first four months

RÉSUMÉ

Cas d enchondrome du tibia chez un homme agé de 66 ans Opération par grattage de la tumeur et insertion de fragments d os prevcles sur les stocks du Centre On a suivi le cours de la guerison par saturation radioactive apres injection de Sr^{85} Quatre ans apres l operation on a constate dans la jambe malade une activite accrue C est pendant les quatre premiers mois que la bipartition biologique a ete la plus élevée

ZUSAMMENFASSUNG

Ein Fall eines Enchondroms bei einem 66jahrigen Mann Operation mittels Auskratzung der Geschwulst und Einlegung von Knochens spahnchen von einer Knochenbank Der Heilungsverlauf wurde mittels Messung der Radioactivitet nach Injection von Sr^{85} verfolgt Noch 4 Jahre nach der Operation zeigt der erkrankte Knochen eine erhohte Aktivitet Die biologische Halbierungszeit war am grossten wahrend der ersten vier Monate

REFERENCES

Bauer Göran C H Rate of bone salt formation in a healing fracture determined in rats by means of radiocalcium Acta Orthop Scand 23 169–191 1954

Bauer Göran C H & Wendeberg B External counting of Ca^{45} and Sr^{85} in studies of localised skeletal lesions in man J Bone Jt Surg., *41 B* 5 8

Wendeberg B Mineral metabolism of fractures of the tibiae in man studied with external counting of Sr^{85} Acta Orthop Scand Suppl 5 1961

AUS DER ORTHOPÄDISCHEN ANSTALT DER UNIVERSITÄT HEIDELBERG
(DIR. PROF. DR. K. LINDEMANN)

ZUR PROGNOSE UND THERAPIE SCHWERER GLIEDMASSENFEHLBILDUNGEN

Von
K. LINDEMANN

Die Beobachtungen der Zunahme einer besonderen Gruppe hypoplastischer Gliedmassenmissbildungen lenken unsere Aufmerksamkeit wieder vermehrt auf die Frage nach der kausalen Genese solcher Fehlbildungen, zumal sich neuerdings auch besondere Anhaltspunkte für die im Grunde vermeidbare exogene Entstehung durch chemische Noxen ergeben. Es ist wichtig genug, all diesen Fragen nachzugehen.

Auch für den Arzt, der sich mit *Therapie* dieser Störungen zu befassen hat, wird ein systematischer Überblick über die typischen Einzelformen nicht zu entbehren sein. (G. B. *Gruber* beginnt in der Morphologie der Missbildungen das Kapitel über diese Entwicklungsstörungen mit dem Satz: Bei der Vielfalt der menschlichen Extremitätenmissbildungen ist klare *Übersicht* und *Einteilung* erwünscht.) Folgen wir dem Autor in diesem Bemühen, so fällt ein Verständnis für die Bezeichnungen *Amelie* und *Peromelie* nicht schwer. Das Erscheinungsbild ist bei ersterer klar, wenn eine oder mehrere Gliedmassen fehlen. Bei diesen Missbildungen ist das Fehlen des Schultergürtels bzw. des angrenzenden Beckenabschnittes seltener, eher zeigen sich diese Abschnitte unterentwickelt. Häufiger sind kleine Bürzel, kleine Gliedmassenstummel oder fingerartige Gebilde anzutreffen, die späterhin als Antriebskraft für Prothesenfunktionen eine erhebliche funktionelle Bedeutung gewinnen können.

Die *Peromelie* zeichnet sich durch konisch oder quer abgesetzte Stummel aus, denen ebenfalls Bürzel oder Fingergliedstummel anhaften können. Entscheidend für die Einordnung der Peromelie ist die Verkürzung der Extremität nach Art einer Amputation, also das Fehlen des peripheren Anteils.

TABELLE I

Jahr	Amelie	Peromelie	Phokomelie	Ektromelie	Kombination mit Hüftdysplasie
1953	1		1	6	–
1954	–	–	–	4	–
1955	–	–	–	7	–
1956	–	1	–	1	–
1957	1	–		4	–
1958	–	1	1	5	–
1959	1	1	–	6	2
1960	–	1	3	18	4
1961	–	1	5	26	10
	3	5	10	77 = 95 Fälle	

Die Bezeichnung *Phokomelie* (Robbengliedrigkeit) stammt von *Geoffroy St. Hilaire*. Hände und Füsse setzen unmittelbar oder nahe an Schulter oder Becken an. Meist sind diese Anhängsel verkümmert. Der Vergleich mit der Seehundflosse ist zweifellos sehr anschaulich. Er dürfte jedoch in den wenigsten Fällen zutreffend sein. „Klassische Phokomelien sind selten", sagt *Gg. B. Gruber*. Folgen wir den Autoren, die bestimmte Ausdrucksformen der Mikromelie als Phokomelien auffassen, wie es *M. Salmon & R. Virchow* getan haben, so würde diese Ansicht zu Unklarheiten in der prognostischen Beurteilung und bei der einzuschlagenden Therapie führen.

A. Werthemann bildet ein geradezu klassisches Präparat einer isolierten Phokomelie des linken Armes im einschlägigen Kapitel des Handbuches der speziellen pathologischen Anatomie und Histologie (9. Abschnitt 6, Seite 116) ab. Auch *Werthemann* lässt die Robbengliedrigkeit nur dann gelten, wenn Hand oder Fuss direkt der Schulter bzw. dem Hüftgelenk ansitzen. Es kann nur zu Missverständnissen und zu erschwerten Vergleichsmöglichkeiten führen, wenn die klassische Einteilung dieser Missbildungen unberücksichtigt bleibt. So ist *O. Hepp* in der Aufschlüsselung der in Münster von 1948–1961 aufgezeichneten Fälle so vorgegangen, dass er die Ektromelien mit Ausnahmen der peripheren Hypoplasien, die sich als Spalthände und -füsse darstellten, zu den Phokomelien gerechnet hat. Eine ähnliche Aufschlüsselung zeigt sich auch in den von der Michigan Children Commision (U.S.A.) mitgeteilten Übersicht.

Häufiger als echte Phokomelien finden wir die im Erscheinungsbild

recht mannigfache *Ektromelie*, also die Fehlstellung einer oder mehrerer Gliedmassen, welche mit einer Hypoplasie oder Aplasie einzelner oder mehrerer Röhrenknochen einhergeht, oftmals aber auch mit qualitativen Abweichungen vor allem im Bereich der Gelenke verbunden ist.

Das sind also rückläufige Bildungen höheren Grades (*A. Werthemann*), die auch durch die Bezeichnung axiale Hypo- und Aplasie anschaulich gemacht werden können. Betreffen die Veränderungen vornehmlich die *distalen* Abschnitte (Strahlenmangel), kann mit dem Fehlen des Daumens beispielsweise eine Unterentwicklung der Radius verbunden sein; liegt die Aplasie distal im *mittleren* Abschnitt des Gliedes, so resultieren daraus Spalthände und Spaltfüsse. Es wird im Einzelfall immer wichtig sein, die Abweichungen im *einzelnen* zu bestimmen. Ist im wesentlichen der proximale Anteil betroffen, so ergibt sich eine auffallende Verkürzung der Extremität. Es bleibt aber durchaus abzuwarten, wie sich postnatale Entwicklung und Wachstum weiter verhalten. Spätere Verknocherungen der Anlagen und spontane Korrekturen der primären Deformitäten sind dem Beobachter dabei durchaus bekannt. So hatte nach dem Beispiel von *Gruber* (Abb. 33 und 34 im Kapitel über Hypoplasien, Mikromelien usw. von *Gruber* auf Seite 306) ein hypoplastischer femur innerhalb von 2 Jahren das Wachstum weitgehend nachgeholt.

Kürzlich wurde mir ein 2½ jähriges Mädchen mit einer isolierten einseitigen, aber sehr ausgeprägten Ektromelie des rechten Armes vorgestellt. Die Mutter belegte den unmittelbar nach der Geburt erhobenen Befund durch eine Photographie. Aus dem zunächst sehr verkümmert erscheinenden hypoplastischen Glied von der Länge eines Zeigefingers ist im Laufe von 2½ Jahren ein Glied geworden, das sich wie folgt beschreiben lässt:

Das rechte, etwas hypoplastisch erscheinende Schulterblatt steht etwas höher als links. Im Schultergelenk ist lediglich die Aussendrehung um die Hälfte eingeschränkt. Der rechte Oberarm hat eine Länge von 13 cm, der linke eine solche von 16 cm. Das rechte Ellenbogengelenk ist in einer Beugestellung von etwa 100 Grad klinisch versteift; der anschliessende Unterarm weist nur etwa halbe Länge des linken auf. Die Hand mit nur 2 Finger- und Mittelhandstrahlen steht in stärkerer Volarflexion und Ulnarabduktion und ist ausserdem um etwa 25 Grad proniert. Aktiv ist nur eine geringe Dorsalflexion möglich. Die beiden Finger, von denen der radiale zweigliedrig, der ulnare dreigliedrig ist, sind bis zur Höhe des Endgelenkes in einer Syndaktylie verbunden. Das Kind kann mit der Hand etwas greifen und mit den Fingerspitzen den Mund erreichen.

Freilich wird der Arm dieses Kindes im Verhältnis zum gesunden immer kürzer bleiben. Er hat sich aber doch innerhalb weniger Jahre

entgegen den Möglichkeiten einer echten Phokomelie zu einer Gliedmasse entwickelt, die bereits jetzt gebraucht wird und deren Funktion durch Übung weiterhin verbessert werden kann. Somit sprechen auch klinisch-therapeutische Gesichtspunkte dafür, die Trennung der Phokomelie von der Ektromelie – der axialen Hypo- und Aplasie – aufrecht zu erhalten. Der Ektromelie liegen im Gegensatz zur Phokomelie Entwicklungs- und Wachstumstendenzen inne, die für Prognose und Therapie zu berücksichtigen sind.

Nach dieser Einteilung haben wir nun unsere Fälle der Jahre 1953–1961 geprüft und in der Tabelle 1 zusammengestellt.

Während im Vorkommen der seltenen Amelie und Peromelie kein Anstieg zu verzeichnen ist, hat die *Phokomelie* in den Jahren 1960–1961 deutlich *zugenommen*.

Bei der *Ektromelie* beträgt die jährliche Durchschnittszahl für die Zeit von 1953 bis 1959 4,5. In den Jahren 1960 und 1961 waren es 18 bzw. 26 Fälle. Eine beträchtliche Zunahme steht also ausser Zweifel.

Unsere Feststellung deckt sich mit Mitteilungen über die Zunahme dieser Extremitätenmissbildungen in anderen Gegenden Deutschlands (*Hepp, Herbig, Imhauser, R. A. Pfeiffer & W. Kosenow, Wegerle* u. a.).

Betrachten wir die Gruppe der Ektromelien im ganzen, so zeigt sich, dass doppelseitiges Vorkommen überwiegt. An der oberen Gliedmasse sind Radiushypoplasie mit fehlendem Daumen und entsprechender radialer Abweichung der Hand und an der unteren Gliedmasse der Tibiadefekt mit Verbiegung der hypoplastischen Fibula und mehr oder minder ausgeprägter Klumpstellung des hypoplastischen Fusses am häufigsten anzutreffen. Von einer weiteren Aufzählung der Abweichungen im einzelnen wollen wir absehen. Die Häufung dieser Gliedmassenmissbildungen gibt nun wichtige therapeutische Fragen auf, zumal die besorgten Eltern vom Arzt eine klare Antwort erwarten.

In der frühzeitigen Behandlung dieser Kinder ist der Gesichtspunkt der Funktion voranzustellen, also Bewegungen durch Übung zu fordern, die Wachstumsrichtung deformer Gliedmassenabschnitte im Hinblick auf den späteren funktionellen Gebrauch zu beeinflussen, unter diesem Gesichtspunkt störende Achsenabweichungen operativ zu korrigieren und bei Amelien und echten Phokomelien trotz der im 2. Lebensjahr notwendigen Prothesenversorgung bereits in der Säuglingszeit die Füsse im Greifen, Tasten und Spielen zu üben. Von vornherein ist von frühzeitigen Amputationen scheinbar störender peripherer Gliedabschnitte abzuraten.

An der unteren Gliedmasse wird der Gesichtspunkt im Vordergrund

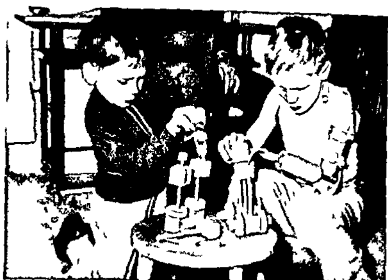


Abb. 1.
Einseitige Peromelie des Unterarms bei einem 3- und bei einem 10jährigen Knaben. Beide wurden mit aktiven Greifarmen versorgt, die im alltäglichen Leben beim Spielen und bei dem 10jährigen auch in der Schule vollwertig ausgenutzt werden.

stehen alle notwendigen Massnahmen auf die Vorbereitung zur Versorgung mit Prothesenschienen oder orthopädischen Schuhen abzustimmen. Führen im Laufe des ersten Lebensjahres korrigierende Redressionen nicht zu dem erstrebten Ziel einer achsengerechten Einstellung der Gliedmasse für die orthopädische Versorgung, so können offene Operationen Anwendung finden wie korrigierende Osteotomien zur Beseitigung von Deformitäten oder von Torsionsfehlern, Muskel- und Sehnenverlängerungen oder die Beseitigung von Luxationen im Bereich des Knie- oder Sprunggelenkes.

Dass gerade bei peripherer hypoplastischer Missbildung die Leistungsfähigkeit im Gehen gut sein kann, zeigt die von *R. v. Volkmann* 1872 beschriebene kongenitale Luxation beider Sprunggelenke bei Vater und Sohn. *Von Volkmann* schreibt ausdrücklich, dass trotz der schweren Fehlbildungen sein Patient ein relativ guter Fussgänger sei, der stundenlange Wege zurücklege.

Im allgemeinen bestanden auch bei doppelseitiger Ektromelie der Beine keine Schwierigkeiten, die Kinder gehfähig zu machen. Das Problem wird dadurch erleichtert, dass diese Kinder ohne Ausnahme eine normale Intelligenz aufweisen und ihr Wille, es den Altersgenossen gleichzutun, damit nicht beeinträchtigt ist.



Abb. 9

Amelie beider Arme, 5jährig, mit einer pneumatischen Prothese versorgt. Beiderseits kräftig ausgebildeter Schultergürtel infolge mehrjährigen Gebrauchs der Prothese. Gut trainierter linker Fuß. Die Prothese besitzt ein aktives Greifvermögen der Hand, eine aktive Handdrehung um 1 0 Grad, aktive Beugung, Streckung und F t tellung des Ellenbogengelenks s ie e n zweiach ige passives Schultergelenk und ein Oberarmrotationsgelenk. Sämtliche Funktionen werden mit großer Geschicklichkeit bedient.

Arthrodesen sind während der ersten 12–14 Lebensjahre kontraindiziert, das gilt besonders für das Handgelenk bei radialer Abweichung der Hand infolge Radiushypoplasie. Die Hand – auch die fehlerhaft ausgebildete Hand – soll für den Gebrauch in dem vor dem Rumpf gegebenen Spiel- und Arbeitsraum beweglich bleiben. Auch hypoplastische Hände an verkürzten Armen haben schon in der Säuglingszeit die im Spiel erlernte und übungsbereite Fähigkeit des beidseitigen Greifens nach dem Ball, dem Würfel oder dem Rundholz. In einer ganzen

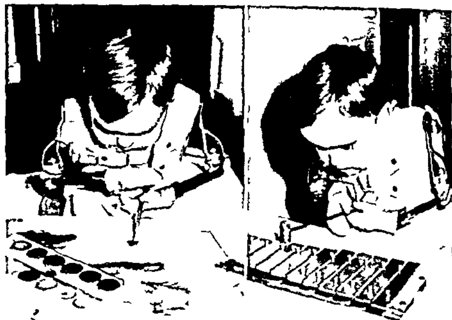


Abb 3

2 Jahriges Kind Amelie links Phokomelie rechts
Pneumatische Betatigung der beiden Babyhandchen im Spiel Der rudimentare Finger an der re Schulter wird fur die gegenseitigen Sichelbewegungen als Antriebsquelle ausgenutzt und unterliegt dabei einem standigen Training Vorbereitung fur die Versorgung mit pneumatisch gesteuerten Greifarmen

Reihe von Beispielen berufstatiger Frauen mit verkurzten Armen und hypoplastischen Handen lasst sich belegen wie ausgezeichnet diese Hande bei mechanischen Verrichtungen (Schneiderei Naherei) oder bei geistiger Tatigkeit wie im Beruf der Lehrerin gebrauchfahig sind Wohl ist es notig auf die *Beseitigung* von storenden *Kontrakturen* im Handgelenk schon in den ersten Lebensmonaten bedacht zu sein damit der Hand die Wachstumsrichtung in der Achse gewahrt wird ohne dabei die Forderung aktiver Bewegungen einzuschranken

Kleinere Gliedmassenstummel die unmittelbar der Schulter ansitzen oder echte Phokomelien konnen durch Ubungsbehandlung in ihrer Kraftleistung ausserordentlich gefordert und so fur die spatere Steuerung einer Prothese vorbereitet werden

Auch beim Fehlen der oberen Gliedmassen gilt fur uns der Grundsatz die Kinder fruhzeitig etwa vom Beginn des zweiten Lebensjahres an mit dem Gebrauch von aktiven Prothesen vertraut zu machen Wir konnen in Ubereinstimmung mit *O Hepp* die gunstigen Erfahr

ungen die von amerikanischer Seite über die Versorgung im frühen Kindesalter berichtet werden, voll und ganz bestätigen. Die Meinung der Stumpf wäre und bliebe die beste Prothese, kann als überholt angesehen werden. So zeigte sich, dass auch Kinder mit einseitigem Fehlen einer Hand oder eines Armes die Prothesen innerhalb von Tagen oder Wochen wie einen zugehörigen Körperteil in Gebrauch nehmen (siehe Abb. 1). Eine besonders schnelle Gewöhnung an den Gebrauch eines Kunstarmes zeigen uns die Kinder mit doppelseitiger Phokomelie oder Amelie der oberen Extremitäten (siehe Abb. 2 und 3), bei denen die Anwendung zusätzlicher Kräfte in Betracht kommt, wie sie die Heidelberger pneumatische Prothese darbietet (nähere Beschreibung bei *E. Marquardt*).

Unsere Beispiele erweisen eindeutig, dass es auch in den Fällen schwerster Gliedmassenfehlbildungen möglich ist, schon im frühen Kindesalter die Voraussetzungen für eine vollkommene Rehabilitation zu schaffen.

ZUSAMMENFASSUNG

Verfasser berichtet über auffallende Zunahme schwerer Gliedmassenfehlbildungen im Verlauf der Jahre 1960 und 1961, besonders der Phokomelie und Ektromelie.

An der klassischen Einteilung derartiger Missbildungen wird im Hinblick auf die Prognose und Therapie festgehalten. Es werden Grundzüge der Therapie bezüglich der Rehabilition armloser Kinder erörtert.

SUMMARY

The author gives an acount of an increasing number of severe congenital malformations, especially cases of Phocomelus and Ectromelus during 1960–1961.

Prognosis and Therapy is discussed and plans for rehabilitation of children with loss of both arms.

RÉSUMÉ

L'auteur rend compte d'un nombre croissant de malformations congénitales graves et en particulier de cas de phocomélie et d'ectromélie dans les années 1960–61.

Le pronostic et la thérapie sont discutés et des plans de revalidation des enfants qui ont perdu les deux bras sont indiqués.

LITERATUR-VERZEICHNIS

Gruber, G. B. in *Schwalbe-Gruber*: Die Morphologie der Missbildungen der Menschen und der Tiere. Jena 1937, Teil 3, K. VII, S. 300 ff.

Hess, O.: Die Haufung der angeborenen Defektmissbildungen der oberen Extremitaten in der Bundesrepublik Deutschland. Med. Klin. 57 (1962) 419-426. „Möglichkeiten der Orthop. Versorgung im Kindesalter". Jb. d. Furs. Korp. 1962 S. 59.

Hoff, A.: Die angeborenen Veranderungen des Unterarms und der Hand. Handb. d. Orthopadie Bd. III, S. 419-506, Stgt. 1959.

Lindemann, K.: Die angeborenen Deformitaten des Unterschenkels. Handb. der Orthopadie IV, 2. Teil, S. 741 ff. Stuttgart 1961.

Lindemann, K. u. *Marquardt, E.*: Mitteilung uber Standardprothesen-Versorgung bei armlosen Kindern. Die Rehabilitation 1 (1962) S. 33-36.

Marquardt, E.: Pneumatische Armprothesen bei Kindern. Jb. Furs. Korperbehinderte. Stuttgart 1962, 82 ff. Aktive Prothesenversorgung eines armlosen Kleinkindes im 2. Lebensjahr. Jb. Furs. Korperbehinderte. Stuttgart 1962, 245 ff.

Pfeiffer, R. A. u. *Kosenow*: Zur Frage einer exogenen Verursachung von schweren Extremitatenmissbildungen. Munch. Med. Wschr. 104 (1962) S. 68-74.

Rütt, A.: Der kongenitale Femurdefekt. Hanb. der Orthopadie Bd. IV, S. 190-196. Stuttgart 1961.

Volkmann, R. v.: „Ein Fall von hereditarer congenitaler Luxation beider Sprunggelenke". Dt. ch. Zschr. Chr. II (1873) 539.

Wegerle, H.: Beitrag zur Haufung von kongenitalen Missbildungen der Gliedmassen und ihre mogliche Atiologie. Med. Klin. 57 (1962) 877.

Weil, S.: Die angeborenen Erkrankungen der Schultergegend und des Schultergelenkes. Handb. d. Orthopadie B. III, S. 1-41. Stuttgart 1959.

Werthemann, A.: Die Entwicklungsstorungen der Extremitäten, in Hdb. d. spez. pathol. Anatomie u. Histologie B. IX, 6, S. 59, S. 115/116. Berlin, Göttingen, Heidelberg 1952.

Wiegand, W.: Versorgung von Kindern mit Armprothesen. Jb. d. Furs. f. Korp. Stuttgart 1962, S. 80.

CONGENITAL ABNORMALITIES OF THE FEMUR

A brief review of the cases observed at the Alfred I. du Pont Institute and a report of the treatment of one case of partial absence

By

A. R. SHANDS, JR. and G. DEAN MACEWEN

The treatment of congenital abnormalities of the long bones, and particularly those of the femur, has always constituted a challenge. This is a report of how such a challenge was met in a child with partial absence of the femur, and a brief report on all of the cases of congenital changes in the femur observed between July 1940 and May 1962 at the Alfred I. du Pont Institute.

The senior author should first like to say how delighted he is to be asked to participate in this homage to two great Swedish physicians who have done so much for the advancement of orthopaedic surgery through their teaching, writings and research, and to wish them long life and many, many more years of productive service.

Congenital abnormalities are constituting an increasing percentage of the patients in the crippled children's hospitals in America as the percentage of patients with poliomyelitis and bone infection is decreasing. At our institution, over a twenty-one year period, the number of patients with congenital malformations has varied from 27.6 to 65.7 per cent of the total admissions, and for four years, from 1953 to 1957, constituted 58.3 per cent of all admissions. The defects and abnormalities of long bones have not been a large percentage of the total number, but have always constituted an interesting and challenging group of cases. In 8500 children examined from July 1940 to May 1962 there were twenty-four who had congenital changes of the femur, representing 2.2 per cent of the approximate 1100 major congenital anomalies[1] observed during this period. Twelve of these had a shorte-

[1] Cerebral palsy, congenital developmental errors of the skeleton and hemangiomata are not included.



Fig. 1



Fig. 2

Fig. 1. Patient at 5 months of age showing marked shortening of right lower extremity with flexion contracture of hip and knee.

Fig. 2. Roentgenogram at 5 months of age showing partial absence of right femur, lack of development of right acetabulum and absence of upper right fibula.

ning varying from 14.3 cms. to 1.4 cms., and twelve had major defects; seven of the latter were bilateral. Four of the twelve with shortening had an associated absence of the fibula. There were sixteen girls and eight boys. The best classification of the congenital defects of the femur was given by *Max Reiner* in 1901 and is as follows:

I. A short femur due to a delayed development with a coxa vara.
II. Femur consists of upper and lower ends with one or more bony nodules present in the region of the absent shaft.
III. Femur consists of a lower end alone united to the tibia. One or more bony nodules may be present in the region of the upper shaft and head.
IV. The upper end of the femur is curved and is sometimes luxated and not differentiated as to head and neck.
V. The hip and knee joints develop but the shaft is greatly shortened.

The nineteen defects in the twelve cases classified according to *Reiner* were as follows: 5 in Class I, 6 in Class II, 5 in Class III, 3 in



Fig 3

R ntgen gram at 1? years 8 m nths of age showing absence of upper p rtion of right femur two bon nodules at upper end of femur and one n dule which probably represents the head of the femur below and medial t upper end of the femur in a small undeveloped acetabulum

Class IV and none in Class V The case reported falls in Class II Six of the twelve cases had other associated major congenital anomalies In this latter group there were three with congenital amput itions

CASE REPORT

Carl RAK was born March 15 1946 and first seen when f ur and one half m nths f age At this time the right l wer extremity was 9 ms h rter than the left The right hip wa flexed and there was a very short thick thigh (Fig 1) The right f t and l wer leg apparently were n rmal a were all ther parts f the b dy

R entgen grams taken at fi e month (Fig 2) showed an ab ence f the upper tw -thirds f the right femur The acetabulum wa hall w Th re wa a hyp plasia f th right fibula The right f t wa n rmal It is intere ting t n te that the m ther ha l a congenital disl cation f the hip which had had an open reducti n when he wa f ur years of age

At the age f f urteen m nths an ext nsion brace wa applied t the right l wer extremit which en bled the patient to ambulate The hil l wa n t en again at the In titute until Octob er 28 19 8 when h w twelve and ne half years ll At this time he was walking with an i chial we ght bearing brace Th re wa a 90 degree flexi n c ntracture f the right knee with m ti n fr m 90 degree t 1 0 degree The right hip was held in a flexe l an l abdu t d p iti n an l the thigh wa extrem l h rt R entg n gram (Fig 3) h w l tw l ny n dules b ut the upper end f a thin narr w femur and a thir l l ny n dule bel w an l med al t the upp r end f th f mur n what l ked l ke a mall unde el pel ace tabulum Thi pr bab l repr ent what might have devel pe l in t the hea l f

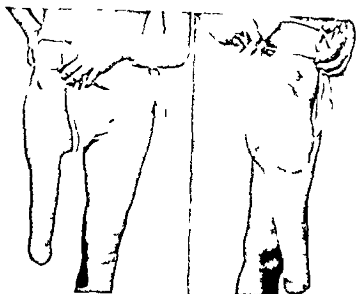


Fig 4
Photograph showing right lower extremity amputation stump front and side views.

the femur The right knee joint was essentially normal and the fibula continued to show the hyp pla ia

Since the childe and parents were anxiou to have omething d ne which would decrease the unsightliness of the extension brace prosthesis and enable her to have a better gait the following was decided upon The foot would be removed the knee would be fused the contracture at the hip joint would be released and an above knee (AK) prosthe is would be fitted

When the child was thirteen years old on April 23 1959 a successful knee arthr desis was performed and held with Charnley clamps Two and one half m nths later a soft tissue release of the contracted ti sues about the right hip and a Syme s amputation were d ne It was not possible t reduce all of the contracture of the hip with surgery The bilateral hip spica cast which had been applied f ll w ing operation was twice wedged at the hip on the right in order to decrea e the flexion deformity The lower end of the right extremity was now opp site the level of the left knee joint (Fig 4) Three months following the last operation the child was fitted with an above knee quadrilateral ocket prosth sis with a p lvic band (Fig 5) At the time the prosthesis was fitted the right hip had an extension to 185 degrees from 90 degrees flexion with a 5 degree flexion contracture adduction was possible to 60 degrees and abduction to 40 degree At first on walking there was a marked gluteu maximus limp which disappeared after gait training

COMMENT

This case represents a very satisfactory functional and cosmetic result with which the patient and family were well pleased She is now

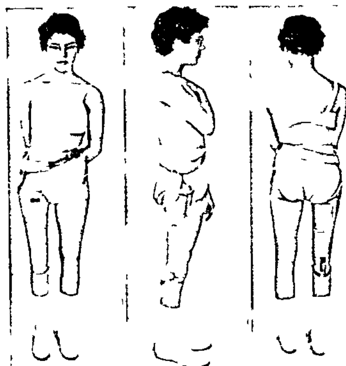


Fig 5
Patient at 14 years of age showing right lower extremity prosthesis front side and back view

able to ambulate extremely well and participate in social and school activities without the embarrassment of an unsightly prosthesis

The procedure employed in this case is not original *Morris* (7) in 1938 reported a patient for which the same general type of procedure had been done *Farmer* and *Laurin* (4) had reported previously a case treated in this way *Morris* has advocated amputation of the foot and a prosthesis for these cases at a very early age He states that the surgical treatment of these anomalies cannot be standardized because of the wide variety of the type of congenital defects in the lower extremities The authors certainly concur with this opinion There are many reports in the literature on the treatment of congenital absence of the femur but only an occasional mention is made of foot amputation and a prosthesis In 1939 there was an excellent report of two cases by *M B Acker* (1) in which a prosthesis had been fitted without amputation of the foot

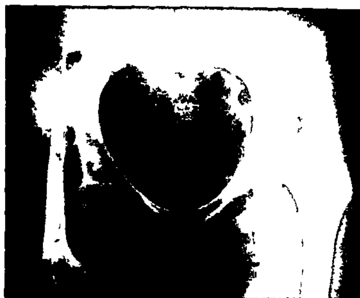


Fig 6
Roentgenogram at 16 years of age showing fusion of knee with bony nodules at upper end of femur as seen in Fig 3

The rarity of this condition is brought out in a report by *Brussel* (?) in 1939 in which he states that only 104 cases of congenital absence of the femur had been reported up until that time and refers to the work of *Harald Nilsonne* (8) who in 1928 collected seventy two cases ten of which were his own

One of the best classifications and descriptions of congenital defects of the femur as well as of the fibula and tibia was given by *Freund* (5) in 1936 who believed that the short femur was a hypoplasia and represented the mildest form of disturbance of growth however some authors believe congenital coxa vara to be the mildest form *Nilsonne* doubts very much whether a general hypoplasia of the femur should be classified with congenital defects *Ollerenshaw* (9) states that the femur is fifth in order of frequency in congenital defects of long bones the fibula tibia ulna and radius being the first four in this order There is a very good report of a post mortem examination of a case by *Manohar* (6) of India in 1939 This contains an excellent description of the muscle abnormalities about the hip joint The patient was fifty two years old when he died and had always used a crutch

One can only surmise as to the cause of congenital anomalies Some have said that 50 per cent of the congenital malformations are genetic

in character but others doubt this high percentage and believe it probably to be as low as 20 Since the limb bud for the lower extremity appears in the third week and the first ossification center of the femur appears on the forty second day with three centers appearing at the proximal end one in the middle and one in the lower end it is quite likely that a disturbance in the development of these ossification centers might be one of the causes It is the authors firm belief that most congenital malformations come from a cell nutritional disturbance at the time of the cell division which in the lower extremity is from the fourth to the sixth week of foetal life This opinion is concurred in by *Ollerenshaw* The excellent work of *Warkany* (13) on vitamins and diet in rats and of *Duraiswami* (3) on hormones in chickens must always be considered when trying to give an explanation of congenital malformations

SUMMARY

1 A review of the congenital abnormalities in the femur observed at the *Alfred I du Pont Institute* has been presented
2 A report on a satisfactory treatment of a case of congenital absence of the proximal end of the femur has been given
3 A brief review of the literature with a few remarks on the etiology of congenital malformations has been included

RESUME

1 Presentation d anomalies congenitales du femur observees par *l Institut Alfred I du Pont*
2 Compte rendu du traitement satisfaisant de cas ou il y a absence congenitale de l extremite proximale du femur
3 Examen succinct de la litterature avec quelques remarques sur l etiologie des malformations congenitales

ZUSAMMENFASSUNG

1 Eine Übersicht der angeborenen Abnormitäten des Femurs die im *Alfred I du Pont Institut* zur Beobachtung kamen ist vorgelegt worden
2 Ein Bericht über die erfolgreiche Behandlung eines Falles von angeborenem Fehlen des proximalen Femurendes wurde gegeben

3 Eine kurze Übersicht der Literatur mit einigen Bemerkungen zur Ursache von angeborenen Missbildungen wurde hinzugefügt

REFERENCES

1 *Acker R B* Congenital absence of femur and fibula Report of two cases Clin Orthop 15 203-7 Winter 1959

2 *Brussel J A* Congenital absence of (femur) bones of lower limb (case with psychosis) J A M A 112 1050 1052 March 18 1939

3 *Duraiswami P K* Comparison of congenital defects induced in developing chickens by certain teratogenic agents with those caused by insulin J Bone and Joint Surg 37-A 277-294 April 1955

4 *Farmer A W and Laurin C A* Congenital absence of the fibula J Bone & Joint Surg 42A 1-12 January 1960

5 *Freund E* Congenital defects of femur fibula and tibia Arch Surg 33 349-391 September 1936

6 *Manohar K* Congenital absence of right femur Brit J Surg 27 158-161 July 1939

7 *Morris H D* Amputations for congenital anomalies of the lower extremities Amer Aca Orth Surg Instructional Course 15 255 261 1958

8 *Nilsonne H* Ueber den kongenitalen femurdefekt Arch f Orthop 26 138 1929

9 *Ollerenshaw R* Congenital defects of the long bones of the lower limb contributions to study of their causes effects and treatments J Bone & Joint Surg 7 528-552 1925

10 *Reiner Max* Ueber den congenitalen femurdefect Ztschr f Orthop Chir 9 544 1901

11 *Shands A R Jr* Congenital absence of the femur patella tarsal scaphoid and ischium associated with other abnormalities Am J Roent & Rad 19 531-539 1928

12 *Shands A R Jr and Peacock H K* Congenital malformations of the skeletal system observed in a crippled childrens hospital over a 17 year period 0th Sicot Congress Transactions 938 947 1957 published in Brussels

13 *Warkany J* Etiology of congenital malformations Advances Pediat 2 1 63 1947

DYSPLASIA EPIPHYSIALIS PUNCTATA

By

TORSTEN JERRE

Dysplasia epiphysialis punctata (D.e.p.) seems to be a rare disease and as far as the author can discover, only one case has been published in Sweden (*Jorup*, 1944). There may perhaps be good reason therefore to review briefly the disease and to present one case which the author recently had opportunity to observe.

This was a girl, born 29/3 1959. She came to the Orthopaedic Clinic, Västerås, for the first time on the 26/9 1960. There was nothing of interest hereditarily. No malformations were known in the family. The mother had the customary childhood ailments but otherwise was completely healthy. There were no diseases during pregnancy. Neurosedyn or anything similar was not used. The delivery was normal. Since the birth the mother had noticed that the girl had a malposition of the right knee joint and also a shortening of the right lower extremity. Otherwise she seemed to be completely healthy and of normal development in all respects.

On examination at the Orthopaedic Clinic in Västerås 26/9 1960 the patient showed at 1½ years a right sided shortening of 4 cms, distributed equally between thigh and lower leg and also a valgus position of 20° in the right knee joint. She seemed otherwise to be healthy and normal in all respects.

The girl was earlier a patient at Pediatric Clinics and Orthopaedic Clinics at other places in Sweden.[1]

From the records and X-rays it appears that the patient already at 1 resp. 4½ months had a considerable shortening and also a valgus position in the right knee joint but seemed otherwise to be of normal development.

X-ray examination 14/4 and 29/4 1959 (*Vänersborg*): the thorax, spinal column, skull, both upper extremities and lower left extremity were of normal condition. Within the right half of the pelvis, the right hip joint and right knee joint there were changes typical of dysplasia epiphysialis punctata (Fig. 1 and 2). The proximal

[1] Doctor *Sven Joachimsson*, head of the Pediatric Clinic, Vänersborg, Doctor *Sven Thunström*, head of the Radiological Clinic, Vänersborg, and Doctor *Folke Ståhl*, head of the Orthopaedic Clinic, Borås, were kind enough to put clinical data and X-rays at my disposal. I should like to thank them most sincerely for their help.



Fig 1



Fig 2

Fig 1 X ray 14 4 1959 Within the area of the right iliac crest and in the right hip joint region a large number of calcifying marks can be seen The bone nucleus is not yet visible

Fig 2 X ray 14/4 1959 In the right knee joint there are the same calcifying marks as in the right hip joint The bone nuclei are not yet visible The fibula projects proximally about 1 cm past the tibia
(The many small light patches in the lower third of the picture are due to film defects)

epiphyses of the femur were not yet visible bilaterally The distal epiphyses of the femur and the proximal epiphyses of the tibia were of normal size for this age on the left side but on the right side had not yet appeared

X ray examination 12/8 and 9/9 1959 (*Borås*) the thorax both upper extremities and the left lower extremity were normal The small stippling marks within the right iliac crest area and within the region of the right hip joint had diminished considerably in number Within the femur s distal and within the tibia s proximal epiphysis areas there was a status quo Within the right ankle joint (not previously X rayed) there were the same changes as within the hip and knee joint. All the epiphyses in the lower left extremity were normally developed for the age on the right side they were not visible as yet either in the hip knee or ankle joint.

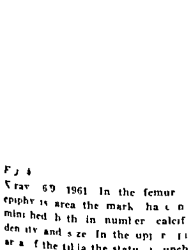
X ray examination 26 9 1960 the thorax spinal column skull and left lower extremity were normal Within the lower right extremity there were changes still typical of dysplasia epiphysialis punctata (Figs 3 and 4)

This disease was described for the first time by *Conradi* in 1914 under the name of chondrodystrophia foetalis hypoplastica Later it was reported under various headings such as epiphysical dysplasia puncticularis chondrodystrophia calcificans congenita chondroangio-



Fig 3

X ray 26/9 1961 The right lower extremity is underdeveloped with a shortening of the femoral and tibial diaph es of ? cms each The fibula the shortening of which scarcely reaches 1 cm is abnormally long in relation to the tibia above all proximally The marks observed earlier in the area of the right iliac crest have now completely disappeared The marks in the right hip joint region have further considerably diminished both in number and in calcification density but still appear plainly on the original film All the bone nuclei also appear now on the right side but are much lesser in size than on the left side The difference in this respect was most pronounced between the distal femoral epiphyses There was a moderate valgus position in the right knee joint





F g 4

X ray 6 9 1961 In the femur di tal epiphy is area the mark ha e n w d mini hed b th in numb er calcif cati n den ity and s ze In the upp r piphysis ar a f the tibia the statu i unchanged

pathia calcarea seu punctata stippled epiphyses dysplasia epiphysialis punctata

The number of earlier published cases was according to *Fairbank* (1949) 16 according to *Mosekilde* (1952) 39 and according to *Weil* (1957) fully 50 *Mørch* (1944) estimates the incidence in Denmark to be 1 in 500 000 newborns or 1 case every 7 years According to the majority of authors the disease is considerably more common in girls than in boys Prevalence in a family was reported by *Maitland* (1939) *Raap* (1943) and *Vinke & Duffy* (1947)

The diagnosis is made radiologically and at least in typical early cases the changes are so characteristic that no differential diagnostic deliberations are necessary The X rays show a varying number of small calcifying marks of unequal size These appear as a rule much before the time when ossification of the epiphysis in question normally takes place (*Brogden & Crow* 1958) indeed their presence has even been confirmed prenatally in the foetus (*Frank & Denny* 1954) In those cases of D e p observed over a fairly long period of time it was proved that the stippling again disappeared within the course of the first years of life either in such a way that they were gradually resorbed or also in such a way that they were incorporated in the normal ossification centre (*Selakovich & White* 1955)

At the same time as the stippling of the epiphyses it is usual radiologically to be able to observe a retardation in the development of the bone nuclei while growth disturbances in the affected extremities are the rule in D e p

The epiphyses to which the disease is most commonly localised are according to *Fairbank* (1949) the upper and lower ends of the femur upper end of the tibia and upper end of the humerus It also occurs in the lower end of the tibia both ends of the fibula the lower ends of the radius and ulna the bones of the hand and foot the acetabulum ischium and sacrum the patella the ribs the sternum the hyoid the intervertebral discs and vertebrae and even in the synovial membrane of different joints (*Fairbank* 1949 *Mosekilde* 1952 *Swoboda* 1956 and *Weil* 1957) The disease may be localised to one part of the body only but within the same patient may also be distributed over a large number of the above localisations

Various cases of D e p have been examined pathologo anatomically and histologically

Conradi (1914) studied in detail and described the pathologo anatomical and histological findings in a girl who died at the age of 1 month

From the histological research in this case he drew the conclusion that the radiologically demonstrated calcifications represent bone nuclei appearing too early

Harris (1933) reported patchy mucoid degeneration and cystic spaces in the cartilaginous epiphyses particularly near the articular surfaces In some places the areas of degeneration were invaded by blood vessels and a core of fibrous tissue had formed In the vertebral bodies which ossified from two centres there was failure of the usual orientation of cartilage cells and of normal calcification and ossification *Harris* insists that the fundamental error is similar to that which he found in achondroplasia

Burckhardt (1938) examined the histologic picture after test excision on a child 6 months old with radiologically typical dysplasia epiphysialis punctata He considers the fundamental point to be morbid changes in the cartilage a softening of the cartilage or cartilage malacia This author regards the calcified layers characteristic of the disease as a sign of a healing process within necrotic parts of the cartilage

Hassler & Schallock (1940) described the pathologo anatomical findings and the histological pictures in great detail Like earlier authors *Hassler & Schallock* were also able to observe both a great number of calcification foci in separate epiphysis cartilage and also necrotic processes here These authors consider that it is not a question of a primary necrosis with secondary calcification but instead that it concerns a primary calcification with secondary necrosis According to these authors the cause of the primary calcifications would be some form of disturbance in the calcium metabolism

Lund (1942) found that the muscles of the limbs were composed mainly of tough white fibrous tissue and were very short This was the cause according to him of the frequently occurring joint contractures

Karlen & Cameron (1957) described as the important histological abnormality the presence throughout the tissue of the epiphyseal cartilages studied of abnormal circumscribed areas reaching one or two millimetres in size These areas contrasted with the surrounding cartilage in staining darkly and irregularly and they were presumed to indicate sites of calcification Some of them showed proliferation of cartilage cells whereas others showed advanced degeneration of the tissue with complete loss of cells

As possible etiologies individual authors have put forward lues A and D hypervitaminosis hypothyroidism and disturbances in the cal

cium metabolism Later authors were not able to confirm these hypotheses however and the etiology of D e p must still be regarded as completely unknown

Very often D e p is combined with malformations and morbid changes within other organic systems such as multiple joint contractures not solely within those regions which are sites for D e p congenital cataract dyskeratosis hip joint dislocation foot deformities heart complaints cleft palate saddle nose general weakness and mental disturbances

Owing to the simultaneous malformations and diseases a large number according to *Fairbank* (1949) half the number of the published cases were born died or died at a very young age *Mosekilde* (1952) states in this connection that 16 out of 42 known cases died 15 during the first year of life and 1 aged 3½ The cause of death in 5 cases was pneumonia in 5 cases other infectious diseases in 4 cases heart complaints and in 2 cases it was unknown

The author has now followed up his case of D e p for 1½ years with quite frequent clinical and radiological checks and the patient recently at the age of 3 was given a renewed painstaking examination The mother states that the girl has always appeared completely normal in all respects with the exception of the present deformity and the shortening of the lower right extremity

At objective examination the patient still displayed a shortening of the lower right extremity of 4 cms equally distributed between the thigh and lower leg and also a valgus position in the right knee joint of 20 The mobility in the hip knee and ankle joints is normal Otherwise the girl has a quite normal physique and seems happy awake and normally developed for her age both psychologically and somatically Length 90 cms Weight 14 kgs (Fig 5)

X ray examination 5/4 and 6 4 1962 the left lower and both the upper extremities were normal There was still 2 cms shortening of both right femur and tibia The previously described stippling marks no longer appear within the proximal epiphysis area of the femur but still are visible within the femur s distal and the tibia s proximal and distal epiphysis areas (Figs 6 and 7) The femur s proximal bone nucleus is now of normal size There is still a valgus position in the right knee joint of 20

During April 1962 the girl was submitted to specialist examinations by ophthalmologist otolaryngologist pediatricians and child psychiatrists but no malformation or morbid changes could be discerned in the respective organic systems

Laboratory tests	SR 5 mms	
	Hb 84 Red 4 82	
	White 7100 < 3 800 p / 3 300 m	
	Calcium in serum	10 2 mg %
	Phosphorus in the serum	5 5 mg %
	Calcium in the urine	0 1 gm
	PBI	5 9 gamma per cent

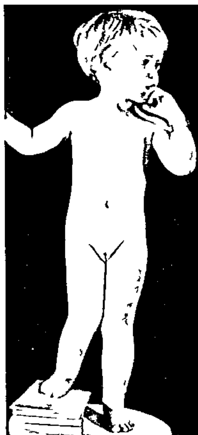


Fig 5
The girl aged 3

The continuing X ray checks showed that the changes typical of the disease gradually diminished Regression began in the regions most proximally situated and since then were observed to take a peripheral direction with increasing age Even at 4 ½ months they had thus become less marked within the iliac crest area and hip joint region At 1 ½ years they had completely disappeared in the area of the iliac crest had further diminished within the hip joint region and also begun to recede in the distal epiphysis area of the femur At 3 years the changes were still quite absent in the area of the iliac crest and had now also completely disappeared in the hip joint region In the distal epiphysis area of the femur they had further receded and now had also begun to be less marked in the proximal epiphysis areas of the tibia but remained without change in the distal epiphysis area of the tibia

That the stippling marks typical of D e p usually recede and disappear with increasing age is a fact known and pointed out by several authors Whether this regression normally occurs in a certain order is not stated in previously published cases nor has it been discussed in earlier literature I wished to point out the course of the regression in my case naturally without drawing any conclusions whether this course would be generally applicable

Taking into consideration the available examination results one may find every justification in this case in expecting a good prognosis for life in the future As the valgus position and shortening has not shown any tendency to increase during 1½ years of observation one may well continue to dare to hope for a really stationary condition

Until now the valgus position in the knee joint has been treated with a non articulated knee cap At a later date prevalent orthopaedic therapy





Fig 6 *Fig 7*

Fig 6 X-ray 6/4 1962 The previously described calcifying marks still appear in in the femoral and tibial epiphyses on the original films however in both places they are lesser in number than before The distal bone nucleus of the femur and the proximal bone nucleus of the tibia have grown considerably but are still lesser in size than on the left side The fibula projects still about 1 cm past the tibia

Fig 7 X-ray 6/4 1962 The calcifying marks still emerge above all laterally in the epiphysis area in approx the same number calcification density and size as before The distal bone nucleus of the tibia has grown considerably but is still lesser in size than on the left side

will in all probability be required in the form of epiphysiodesis and/or corrective osteotomy shortening osteotomy and/or lengthening osteotomy

SUMMARY

The author describes a case of dysplasia epiphysialis punctata and gives in connection with this an account of this rare disease

RESUME

L auteur decrit un cas de dysplasie epiphysialis punctata et donne a cette occasion un compte rendu de cette maladie rare

ZUSAMMENFASSUNG

Der Verfasser beschreibt einen Fall von Dysplasia epiphysialis punctata und bespricht im Zusammenhang damit diese seltene Erkrankung

REFERENCES

Brogdon B G & Crou \ E Chondrodystrophia calcificans congenita Am J Roentgenol 80 443 1958

Burckhardt E Ein Fall von Chondrodystrophia fetalis calcarea Schweiz Med Wochenschr 68 330 1938

Conradi E Vorzeitiges Auftreten von Knochen – und eigenartigen Verkalkungs kernen bei Chondrodystrophia fotalis hypoplastica Histologische und Rcnt genuntersuchungen Jahrb f Kinderheilk 80 86 1914

Fairbank H A T Dysplasia epiphysialis punctata J Bone & Joint Surg 31 B 114 1949

Frank W W & Denny M B Dysplasia Epiphysialis punctata J Bone & Joint Surg 36 B 118 1954

Harris H A Cit from Fairbank (1949)

Hä sler F & Schallock G Chondrod strophia calcificans Monatschr f Kinderheilk 8' 133 1940

Jorup S Fall von Chondrodystrophia congenita cal ificans Acta radiol 25 580 1944

Karlen A C & Cameron J A P Dysplasia epiphysialis punctata J Bcne & Joint Surg 39 B 293 1957

Lunl E Metaphyseal Dyscrasia Proc Roy Soc Med 36 381 1942

Ma llanl D G Punctate Epiph seal D spla ia occurring in two members of the same family Brit J Radiol 12 91 1939

Mos kil le E "Stippled epiphyses in the newborn and in infants Acta radiol 37 291 1952

M rch F T Diskussionsinlagg Nord Med 21 375 1944

Raap C Chondrodystrophia Calcificans Congenita Am J Roentgen 1 49 17 1943

Selakovich W G & White J W Chondrod strophia alcificans congenita J I ne & Joint Surg 37 A 1271 1955

Swob la W Das Skelett des Kindes Stuttgart 1956 50

We l S Die angeborenen Skeletts stemerkrankungen Handbuch d r Orth ; adie v n Hohmann Hackenbroch und Lindemann Band I 192 1957

Vinke T H & Duffy F P Chondrod strophia Calcifican Cengenita J Bone & J int Surg 29 509 1947

TREATMENT OF OSTEOMYELITIS AND INFECTED WOUNDS BY CLOSED IRRIGATION WITH A DETERGENT ANTIBIOTIC SOLUTION

By

EDWARD L. COMPERE[1]

Topical treatment of osteomyelitis and infected wounds including old ununited fractures has proved to be successful in a high percentage of cases including those in which the bacterial organism was resistant to most antibiotics Treatment by means of continuous irrigation (or circulation) and suction of the closed wound using a solution containing an antibiotic and a detergent has evolved from theory and trial and error within the last five years

In 1942 *Brantigan & Owens* (1) reported the topical use of sodium tetradecyl sulfate in the treatment of acute pyogenic empyema of the pleural cavity This detergent or "wetting agent is a non specific germicide which proved to be an effective solvent of sputum and empyema fluid There was evidence that it penetrated infected and necrotic tissue *Jeffrey* (2) had observed that penicillin not infrequently did fail even against susceptible organisms in necrotic soft tissue and necrotic bone and in the center of abscesses and masses of fibrinopurulent material

Grace & Bryson (3) in 1945 reported success in the topical use (in three cases of chronic osteomyelitis) of penicillin in a solution of isotonic sodium chloride with 0 1 per cent of the detergent sodium tetradecyl sulfate

In 1947 *Grace & Bryson* (4) reported excellent results following the topical use of a penicillin detergent solution in treating two war veterans who had been discharged from military service with intractable

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osteomyelitis. In this same report they referred to their success in treating a series of 37 civilian patients who were suffering from chronic osteomyelitis.

During the decade following his first successful use of a detergent antibiotic solution, *Grace* and his co-workers were able to effect a cure of many cases of infection by a variety of bacterial organisms, including the tubercle bacillus. Refinements in the technique included the closure of the wound before beginning instillation of the detergent antibiotic solution. Antibiotics which were soluble in the solution and also previously determined to be most effective in in vitro tests were selected. *Mitra* of Calcutta, India, worked with *Grace* in Brooklyn, and in 1957 (6) they reported complete arrest of 64.21 per cent of 95 cases of chronic pyogenic osteomyelitis treated in Calcutta and 69 per cent of 45 similar cases treated at the Grace Clinic, Brooklyn, New York. In these cases the actual surgery performed consisted only of removal of sequestra and other grossly devitalized tissue and opening the medullary canal sufficiently to assure free entry of the detergent antibiotic solution.

The technique which they recommended in 1958 was as follows:

Mix an antibiotic known to be effective in destroying the bacterial organism with 50 cc's of "Aerosol Wash" solution.[1] The amount of antibiotic mixed with this diluted Aerosol Wash should be the equivalent of the maximum amount which would ordinarily be used in a 24 hour period orally or intramuscularly for each 10 cc's of the Wash. Two or more antibiotics have been used simultaneously mixed with the Aerosol Wash. The area from which the drainage is appearing should be opened, definitely necrotic or sequestrated bone removed, a T-tube or urethral catheter inserted, and after thoroughly irrigating the wound it should be closed, leaving the T-tube or catheter in place. Five cc's of the detergent antibiotic mixture should be instilled through the tube three times each day for five to ten days. Cultures should be obtained from the material withdrawn from the tube by suction with a sterile syringe until at least three consecutive negative cultures have been reported. The tube should then be removed.

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[1] "Aerosol Wash" is a detergent solution prepared by American Cyanamid Company—30 Rockefeller Plaza, New York 20, New York. Aerosol Wash solution consists of Aerosol OT 0.68% W/V di (ethylhexyl) ester of sodium sulfosuccinate, Aerosol 0.08% W/V N-octadecyl N (1, dicarboxyethyl) tetra sodium sulfosuccinate with preservative (hexachlorophene). To 50 cc's of the Aerosol Wash add 50 cc's of distilled water.

The technique described was successfully used by me in the treatment of two cases of post operative wound infections of the femur and thigh muscles by resistant strains of staphylococcus aureus organisms which had persisted for long periods in spite of maximum doses of antibiotics administered orally and intramuscularly

Closed continuous circulation of a solution containing antibiotics was first used for patients on the Orthopaedic Service of Chicago Wesley Memorial Hospital *Goldman Johnson & Grossberg* (*1*) resident surgeons in Orthopaedic Surgery described the technique and reported five cases of osteomyelitis which were cured by continuous or intermittent closed irrigation The time elapsed between beginning circulation and healing of the wounds was from one to eight weeks *Dr Robert T McElvenny* (8) developed the detail technique described by *Goldman Johnson & Grossberg* He reported 12 cases treated by this method

In each of my small series of cases I have used a 0 1 per cent solution of Aerosol Wash detergent or 0 5 per cent of Alevaire in normal salt solution as solvent for the antibiotic One gram of Chloromycetin or two grams of novobiocin are added to each liter of solvent Antibiotics were administered orally or intramuscularly during the period of closed irrigation and continued for varying periods after removing the irrigation tubes In each of my cases the material sucked from the closed wound has become sterile within four to seven days after starting the closed irrigation After four consecutive negative cultures the tubes have been removed

Technique of closed irrigation (circulation) of chronic osteomyelitis and other infected wounds

1) Sinuses are excised Sequestra and all necrotic tissues are removed

2) The multiperforated sections of two non pyrogenic plastic tubes[1] (1/8 inch diameter) are laid in the wound Using an 8 inch malleable stainless steel needle threaded on the blunt end to fit into the tubing the non perforated portion of each section of tubing is led out through sound tissue at least one inch from the edge of the wound Each piece of tubing is anchored to the skin with a single fine suture (Figure 1)

[1] The tubing and needles are manufactured by the Snyder Manufacturing Company of New Philadelphia Ohio and are distributed by the Zimmer Manufacturing Company of Warsaw Indiana U S A

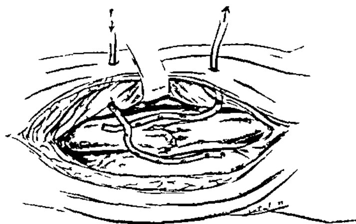


Fig 1
This drawing illustrates the way in which the fenestrated tubes are placed in the wound The detergent antibiotic solution enters through one tube and is sucked out through the other

3) The wound is closed tightly with fine stainless steel sutures

4) The tube for irrigating is attached to an intravenous type of tubing connected with a 1 liter bottle containing the previously pre pared detergent antibiotic solution

5) The second tube is connected to an electrically driven suction machine such as the Chaffin Pratt or the Gomco The negative pressure of the suction machine should not exceed 20 inches of water equivalent

6) The instillation drip rate should be set to deliver about 80 cc s per hour or approximately two liters during each 24 hours

In the beginning continuous suction was maintained with good re sults At the present time intermittent suction is being tried This per mits the wound to fill with the detergent antibiotic solution The suc tion pump is so regulated that every fifteen to twenty minutes it ope rates just long enough to empty the wound of solution and exudate

Two of my cases are presented to illustrate the very gratifying re-sults which have been achieved in a small series

Cas 1 F M C W

This patient aged 53 years wa first n and examined b me August 8 1961 becau e of an infected fracture of th neck of the left femur The fracture had occured December 1? 1960 A Smith Petersen nail with a femoral plate was u ed



Fig 2

Case 1 This roentgenogram shows extensive destruction of the hip including the head and neck of the femur Negative cultures were obtained after less than one week of closed irrigation

December 13 1960 for immobilization of the fracture Twelve days later drainage from the incision began She was treated with Kantrex other antibiotics and vitamins but the drainage continued

My examination showed purulent drainage from a sinus tract near the upper end of the left subtrochanteric operative scar There was also induration all along the upper portion of the scar but the distal portion of the incision was healed X rays showed union of the fracture but definite evidence of necrosis of the head of the femur

The patient was admitted to the Chicago Wesley Memorial Hospital August 1, 1961 and August 14 1961 the plate and nail were removed There was definite purulent material surrounding the nail and plate This was thoroughly irrigated with warm isotonic sodium chloride solution The wound was then closed after inserting irrigation tubes The lower tube was attached to an electric suction pump the upper tube was attached to a 1 liter intravenous flask containing normal salt solution two grams of novobiocin and five cc s of Alevaire One gram of Albamycin was given by mouth each day Two liters of the solution containing antibiotic and the Alevaire detergent were used each 24 hours There was a continuous drip which usually emptied the one liter flask in about 12 hours and then this was changed Gradually the drainage or suction of material from the wound became more clear and free from debris and after one week negative cultures were obtained. After four negative cultures on consecutive days the suction and irrigation tubes were removed The wound healed completely and the patient was discharged.

October 23 1961 about nine weeks after the operation and institution of continuous irrigation and drainage there was a flareup with redness and swelling This subsided with antibiotics taken by mouth but the inflammation recurred and

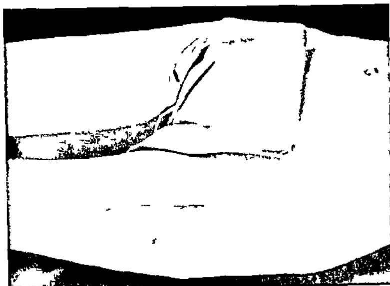


Fig 3

Case 1 This photograph shows the scar of the healed wound The tw dark spots lateral to the linear scar are the sites where the irrigation tubes were brought out through the skin

December 2 1961 more than four months after operation the incision was opened and a large abscess was evacuated This continued to drain until February 1962 when the patient was readmitted to the hospital and on February 20 1962 the sinus tract was dissected out the hip joint was opened widely This time there was extensive purulent material within the joint and partial destruction of the head of the femur (Figure 2) Closed irrigation was again instituted Within f ur days the patient was afebrile Irrigati n was continued with the nov biocin and Alevaire solution as described above After one week cultures became negative and after five consecutive negative cultures the irrigation tubes were rem ed and the patient was discharged March 7 1962 with the wound completely healed (Figure 3)

Case Mal aged 56 years R I P

In April 1961 this fifty six ear old surge n began to suffer from pain in his left tibia about three inches below the knee A r entgenogram revealed a destructive lesi n in the tibia whi h c nsulting phy icians thought was probably a malignancy On perati n however it was found to be an ab cess with thick purulent material and from this was cultured a hemolytic staph lococcus aureus varidase and coagulase positive This proved to be a very resi tant rganism Hemat gen us o te mye litis in an a lult is rare Such infection in this era of antil iotics in a patient 56 ears of age are exceedingly uncommon

S ptemler 24 1961 while th patient wa swimming in the cean although he till had a d aining sinu a l rge l g which was partiall submerge l was brought



Fig 4

Case 2 Completely healed hematogenous osteomyelitis of the tibia Purulent drainage had been continuously present for eight months Sterile cultures were obtained after four days of closed irrigation with the detergent antibiotic solution

in on a wave and struck the left tibia This caused a fracture of the tibia through the site of infection October 23 1961 the osteomyelitis area was re explored by Dr *Paul McMaster* of Beverly Hills California and a large sequestrum involving almost the full diameter of the tibia was removed This left a defect of approximately 1-¼ inches which was still present when I first examined him November 18 1961 I advised operation to clean out the necrotic tissue and start continuous irrigation with detergent and antibiotic material

December 1 1961 I carried out the operation in a manner described in a preceding part of this report Before excising the sinus and opening the abscess area in the tibia I did an osteotomy in the lower third of the left fibula and then sealed off this incision In addition to the sinus there developed in the few weeks after my first examination of this patient and before his arrival in Chicago for the operation, a bluish area of necrosis of the skin and subcutaneous tissue about 1 inch medial to the draining sinus This was an unexpected complication but I proceeded to carry out the operation as planned The suction and irrigation tubes were placed in the wound and the incision closed He was given Albamycin mgms 250 four times each day by mouth Continuous irrigation was maintained using the slow drip method. To each liter of isotonic sodium chloride solution was added 5 cc s of Alevaire and 2 grams of novobiocin Two liters were used each 24 hours Once each day the suction tube was disconnected from the Chaffin Pratt electrically driven suction machine a sterile syringe was attached to this tube and strong suction applied. During each of the first three or four days 20 to 30 cubic centimeters of exudate and necrotic material were withdrawn into the syringe This was cultured and the tube connected to the electrically operated suction machine On the fourth day after starting the continuous irrigation the material obtained from the suction tube proved to be sterile and continued to be sterile each day thereafter December 10 1961 nine days after the operation and the institution of continuous irrigation the



Fig 5

Ca e This roentgenogram shows eviden e of healing f the fracture which had occurred through the steom eliti focus

pla ter cast was removed the dres ings wh ch were soaked with exudate as well as with the irrigation soluti n were all removed The 1–¼ t ? cm ar a which had been bserved to be bluish di c lored nd apparentl becoming necrotic had com pletel br ken d wn This necrotic ti sue as remo ed leaving a deep defect The hem vac irrigation and drainag tubes were rem ved and the defect left when the necr ti tissue had been removed was lo sel packed with vaseline gauze A light c mpre ion dressing wa applied fr m the f t to above the knee and a posterior pla ter m ld was band ged firml to the leg

Dec mber ?1 1961 twent da s after the perati n the dres ings were all removed the w und appeared to be clean and the in ision had healed The defect adjacent to the in i i n from which the n rotic ti ue had been removed wa healing A new cast was applied and a walking heel attached to it The patient wa ad ised to begin partial weightbearing and Decemb r ? 1961 he returned to Calif rnia A telephone call Janu ry 30 196? stated that he was ha ing no pain and c uld bear full weight with ut any difficulty The c t whi h had b en applied in Chicag December ?1 1961 rem ved in Calif rnia ab ut F bru ry 15 196 The wound as f und to be

completely healed and the defect created by the removal of the necrotic tissue had also healed. A new cast was applied.

The patient returned to Chicago and was admitted to the Chicago Wesley Memorial Hospital March 12, 1962. When I removed the cast I found slight redness and swelling in the area in which the necrosis had been present. He was last examined by me April 24, 1962. The wound was completely healed and clean; there was clinical evidence of fibrous union of the fracture of the tibia. A new cast was applied. He has been walking with full weightbearing without cane or crutches.

Figure 4 is a photograph of the completely healed wound. Figure 5 is a roentgenogram of the tibia showing callus formation at the site of the infected fracture.

SUMMARY

Continous closed circulation of infected wounds and chronic osteomyelitis with a solution containing a detergent and one or more antibiotics has been successful in eliminating the infection and obtaining healing. In the preliminary reports of the cases treated by this method the results appear to be even more spectacular than those reported by Grace and Mitra in which they instilled antibiotics in a detergent solvent solution. My experience with and observation of a small series of cases treated by each of the three methods encourages me to continue to use the combination of a detergent and antibiotics in a solution of isotonic sodium chloride for closed circulation (irrigation) of cases of chronic osteomyelitis and orthopaedic wound infections. This study is still in a very preliminary phase. After three or four more years I shall hope to be able to report a significant series of end results.

RESUME

Dans les cas de plaies infectees et d osteomyelites chroniques une circulation continue close d une solution contenant un detersif et un ou plusieurs antibiotiques a ete appliquee avec succes. L infection a ete eliminee et la guerison obtenue. Dans le rapport preliminaire des cas traites par cette methode les resultats paraissent encore plus spectaculaires que ceux rapportes par Grace et Mitra dans lesquels il avait instille des antibiotiques dans une solution d un solvant detersif. L experience que j ai retiree de l observation d une petite serie de cas traites par chacune des trois methodes m encourage a utiliser la combinaison d un detersif et d antibiotiques dans une solution de chlorure de sodium isotonique en circulation close (irrigation) dans les cas d osteomyelites chroniques ou de plaies orthopediques infectées. Cette etude en est toujours a une phase preparatoire. Au bout de trois ou quatre ans j espere pouvoir rapporter une serie importante de resultats finaux.

ZUSAMMENFASSUNG

Fortlaufende geschlossene Spulung von infizierten Wunden und chronischer Osteomyelitis mit einer Lösung die ein Detergens und ein oder mehrere Antibiotica enthalt wurde mit Erfolg zur Uberwindung der Infektion und zur Erreichung der Heilung angewendet In den vorlaufigen Berichten uber die Falle die in dieser Weise behandelt wurden erscheinen die Ergebnisse noch aufsichtsweckender als jene die von Grace und Mitra berichtet worden sind und in denen sie Antibiotica gelost in einer Detergenslosung instillierten Meine Erfahrung und Beobachtung in einer kleinen Reihe von Fallen die mit jeder der drei Methoden behandelt wurden ermutigt mich die Kombination eines Detergens und Antibiotica in einer physiologischen Kochsalzlosung fur die geschlossene Spulung (Irrigation) in Fallen von chronischer Osteomyelitis und orthopedischen Wundinfektionen fortgesetzt zu verwenden Diese Studie befindet sich noch in einem äusserst vorlaufigen Stadium Nach weiteren drei oder vier Jahren hoffe ich in der Lage zu sein eine gewichtigere Reihe von Endergebnissen vorzulegen

REFERENCES

1 *Branting n O C & Owens J C* Sodium Tetradecyl Sulfate Used in the Treatment of Acute Pyogenic Empyema of the Pleural Cavity Bull School Med Univ Maryland 26 247 (April) 1942

2 *Jeffrey J S* Application of Penicillin to War Wounds Brit J Surg (Supp) 3 124 (July) 1944

3 *Grace E J & Bryson V* Topical Use of Concentrated Penicillin in Surface Active Solution Archives of Surgery Vol *50* 219–222 (April) 194

4 *Grace E J & Bryson V* Chronic Osteomyelitis in War Wounded A Report of Two Veterans Discharged with Intractable Osteomyelitis and Successfully Treated with Local Penicillin Detergent Therapy N Y State J of Med 47 No 20 2204–2205 October 15 1947

5 *Grace E J* Topical Streptohydrazid Treatment of A Tuberculous Sinus Antibiotic Medicine *1* No 2 104–10 February 1955

6 *Mitra R N & Grace E J* Further Studies on the Treatment of Chronic Osteomyelitis with Topical Detergent Antibiotic Therapy Antibiotics Annual 1956–1957 Medical Encyclopedia Inc New York N Y pp 455–466

7 *Coldman M A Johnson R K & Grossberg N M* A New Approach to Chronic Osteomyelitis Orthopedic April 1960

8 *McElhenny R T* The Use of Closed Circulation and Suction in the Treatment of Chronically Infected Acutely Infected and Potentially Infected Wounds The Am J of Orthopedics March May 1961 pp 86–8 and 154 160

A SERIES OF CEREBRAL PALSY OPERATIONS

By

HARALD NILSONNE

In 1954 and 1955 accounts were published (Swedish Medical Journal and Scandinavian Medicine) of orthopaedic surgical measures for cerebral palsy adopted at the Eugenia Home Clinic

These are supplemented here by a few viewpoints formulated through the experience gained in 770 c p operations

During the earlier period when c p cases were chiefly treated by orthopaedic surgeons no full understanding yet prevailed of the importance of early physiotherapy and this sometimes led to too rapid operation Nor was the differential diagnosis sufficiently developed Sometimes no distinction was made between true spasticity athetosis and conditions of varying tonus

When pediatricians and neurologists began to be interested in this field greater understanding of these brain injuries was achieved and by means of fruitful teamwork the diagnosis and indications were defined more satisfactorily than before

The literature of the last decade gives evidence of a lively interest in active orthopaedics but shows a more critical attitude towards the indications than before

The principles which seem to be accepted in c p surgery have probably been formulated best by *Barnett* (collaborator of the pediatrician *Perlstein* in Chicago) (1) careful evaluation of the total problem must precede any surgical therapy (2) surgery is merely an adjuvant measure and not a substitution for muscle re education (3) surgery will fail without adequate post operative therapy (4) conservative therapy in growing children such as achieved by physical therapy and bracing should always be given an adequate trial before surgery (5) deformities in growing children which are operated on always require post operative bracing in order to prevent recurrence of the deformity (6) surgery must be directed against the primary deforming factors

and is contraindicated if it retards or impairs functional ability and (i) contractures due to postural defects should not be corrected surgically unless the patient will be able to use the extremities in the corrected position

One more point should be added to the above operation ought not to be undertaken during the first years of life

Development takees place very slowly in c p cases and sufficient information about the motor mechanism is not obtained before the child is 3-4 years old sometimes still later

Barnett s principles seem to be the same as those which we have followed at the Eugenia Home for decades We were especially cautious before operation and before this was performed we obtained definite information about the patient s motor system and mental condition and thus we determined the prospects for a postoperative course When an operation is completed it is therefore the result of team work comprising nurses physiotherapists and play therapists while there is the natural collaboration between the orthopaedic surgeon the pediatrician and the child psychiatrist in the clinic

Table of c p operations performed at th Eugenia Home
(smaller simpler operations are not included)

Achillotom (aperta)	33?
Calcaneus plastics	6
Transposition of ant tib muscle	5
Cuneiform osteotomy of tarsus	17
Cuneiform osteotom of tarsu + Stoffel poples	3
Subtalar arthrodesi	12
Osteotomy of torsiones tibiae	3
Transposition of m gastrocnemiu	46
Myotomy poples	47
Myotomy poples + Stoffel pople	38
Stoffel poples	45
Transposition of m semitend	?
Transposition of m rect fem	9
Myotomy of m adduct cox	64
Myotomy of m adduct cox + resection of obturator nerve	38
Resection of obturator nerve	54
Osteotomy of troch maj	4
Stoffel forearm	17
Resection of pron teres	20
Resection of pron teres + quadrat	2
Resection of pr n teres + Stoffel forearms	5
Transposition of flex carp radial	2

To this the following commentary may be added various methods have been discussed in the treatment of pes equinus Achillotomy has come into discredit in certain respects This is probably due to the fact that an overdosed achillotomy brings about a pes calcaneus which is more severe deformity than pes equinus Our 6 cases of calcaneus plastics were thus performed on overdosed achillottomies which came to our clinic The gastrocnemius transposition is theoretically well founded but we have found no difference in effect between these two operations And then the achillotomy is a much simpler operation. There must be the requirement however that it is a surgeon experienced in c p who undertakes the achillotomy since the adjustment at the operation demands experience

Stoffel has a limited field but is yet an operation of a certain value

Obturator resection is never performed by us intrapelvically Two cases were observed where such a resection was previously carried out, after which total adductor paresis with defective hip control arose

Surgery of the arm requires great experience Resection of the m pronator teres generally gives immediate freedom from contracture which is functionally of great value Transposition of the flexor muscles will probably produce better results than those we have hitherto achieved

Inward rotation contractures in the lower extremities of spastics form a difficult problem Torsion osteotomies on the lower leg do not seem to invite further imitation Transposition of the greater trochanter is a theoretically justified intervention However the results have been relatively moderate

If one therefore arrives at the conclusion that physiotherapy commenced early is the main factor in the treatment of c p then however the nerve skeletal and strenght regulating operations have a considerable value

The future points however to brain surgery as the next source of progress

SUMMARY

The author gives an account of cerebral palsy series consisting of 770 operations It is pointed out that the indications must be strict and that a detailed analysis by a c p team should precede the intervention Operations should not be performed during the first years of life The author refers to *Barnett s* principles which are exemplary

RESUME

I auteur rend compte d une serie d observations comportant 770 opérations de paralysies cerebrales Il est souligne que les indications doivent etre rigoureuses et qu une analyse approfondie par une equipe competente doit etre faite prealablement a l intervention Il ne convient pas d operer dans les premieres annees de la vie L auteur renvoie aux principes de *Barnett* qui sont condamnables

ZUSAMMENFASSUNG

Der Verfasser gibt Rechenschaft uber ein Material von 770 Operationen bei cerebraler Lähmung Man hebt hervor dass die Indikationsstellung streng sein soll und dass eine eingehende Analyse vor dem Eingriffe von einem cerebral Parese Team" vorgenommen werden soll Wahrend der ersten Lebensjahren sollte nicht operiert werden Der Verfasser weist auf *Barnetts* Principien hin die zu verurteilen sind

REFERENCES

B rness Orth Surg in C.p Journ Am Med Ass 19 ›

Cruickshank Cerebral palsy Syracuse Press 1955

Henderson Cerebral palsy Livingstone London 1961

Nilsonne Synpunkter på spastikers rden Nord Med 195›

Nilsonne Den ortop beh av c p Sv lak tidn 1954

Ro st Diagnose u Therapie Cerebraler Lahmungen Karger 196›

ÜBUNGSBEHELF ZUR BEHANDLUNG DER DORSAL SKOLIOSE

Ph. J. Erlacher
Wien

In der konservativen Behandlung der Skoliose hat das Milwaukee-Mieder sich einen beachtlichen Platz erobert. Es hat vor den üblichen Skoliosemiedern den grossen Vorteil, dass es die Kinder zur aktiven Mitarbeit zwingt. Während im Redressions- oder Stützmieder durch die Ruhigstellung und den Druck von aussen eine Atrophie der Muskulatur eintritt, stellt das Milwaukee-Mieder die Wirbelsäule nur ins Lot und die unangenehme Kopfstütze ist eine ständige Mahnung und zwingt das Kind unwillkürlich jene Muskeln anzuspannen und zu kräftigen, durch die es die Wirbelsäule im Lot halten und strecken kann.

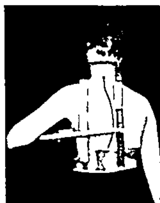
Ein orthopädischer Grundsatz besagt, dass es nicht genügt eine Deformität passiv zu beseitigen, sondern dass auch aktive Kräfte vorhanden sein oder geschaffen werden müssenn, um eine Korrektur aufrecht zu erhalten. Die vollständige Beseitigung einer Skoliose ist nicht möglich, wir können immer nur bessern, vermindern, aber trotz Besserung bleibt ja eine gewisse seitliche Abweichung des Rückgrates bestehen, der Skoliosenkeim wirkt fort. Daher müssen wir für Kräfte sorgen, die einer Zunahme entgegen wirken.

Ohne auf das komplicierte Skoliosenproblem hier näher einzugehen zu wollen, muss festgehalten werden, dass wir bei der Behandlung derselben ständig gegen die Schwerkraft kämpfen, Wirbelkörper und Gelenke umformen und das Muskelgleichgewicht wiederstellen müssten, um den erreichten Erfolg zu sichern.

Von allen bisher bekannten Behandlungsmethoden wirkt gerade das Milwaukee-Mieder in diesem Sinne — wenn es lange genug getragen wird. Das Mieder muss aber solange getragen werden, solange eine Verschlechterung droht, also bis zum Abschluss des Wirbelsäulenwachstums, eine harte Zumutung namentlich für Mädchen. Auch auf diese Schwierigkeiten möchte ich nicht näher eingehen, sondern nur einen



a
Milwaukee Mieder angelegt



b
Behelf befestigt



c
Korrektur durch Anpressen des Armes

Behelf beschreiben, der die aktiven Kräfte zu intensivieren und ihre korrigierende Wirkung besonders auf die Brustwirbelsäule zu verstärken vermag.

Auf ein normales Milwaukee-Mieder, das genau nach den Vorschriften von Walther P. Blount am Beckenkamm exakt anmodelliert sein muss und dessen Kopfstütze nur so hoch sein darf, dass der Kopf noch gut 1 cm darüber hinaus gestreckt werden kann, wird an der Konkavseite ein Bügel aufgesteckt, der eine flache Schale für den Unterarm besitzt. Der Arm ist im Schultergelenk abduziert. Durch Andrücken des Armes an den Körper werden jene Rumpfmuskeln angespannt, die den Rumpf zur Konkavseite hinziehen. Auf die Bedeutung dieser Muskeln zur Behandlung der so schwer zu beeinflussenden Brustskoliose beim Skoliosenturnen hat schon vor 50 Jahren Niederhoffer hingewiesen. Der Behelf kann leicht aufgesteckt und abgenommen werden, dient nur als Übungsgerät, mit dem die Kinder mehrmals täglich üben sollen.

Die Abbildungen a bis c zeigen deutlich die korrigierende Wirkung auf die Wirbelsäule.

ZUSAMMENFASSUNG

Eine einfache Abduktionsschiene, die im Milwaukee-Mieder aufgesteckt wird, kann als Übungsgerät zur Kräftigung der transversal wirkenden Thoraxmuskeln verwendet werden.

UBUNGSBEHELF ZUR BEHANDLUNG DER DORSAL SKOLIOSE

PH J ERLACHER
Wien

In der konservativen Behandlung der Skoliose hat das Milwaukee Mieder sich einen beachtlichen Platz erobert Es hat vor den ublichen Skoliosemieder den grossen Vorteil dass es die Kinder zur aktiven Mitarbeit zwingt Während im Redressions oder Stutzmieder durch die Ruhigstellung und den Druck von aussen eine Atrophie der Muskulatur eintritt stellt das Milwaukee Mieder die Wirbelsaule nur ins Lot und die unangenehme Kopfstütze ist eine standige Mahnung und zwingt das Kind unwillkurlich jene Muskeln anzuspannen und zu kraftigen durch die es die Wirbelsäule im Lot halten und strecken kann

Ein orthopädischer Grundsatz besagt dass es nicht genugt eine Deformität passiv zu beseitigen sondern dass auch aktive Krafte vorhanden sein oder geschaffen werden mussenn um eine Korrektur aufrecht zu erhalten Die vollständige Beseitigung einer Skoliose ist nicht moglich wir konnen immer nur bessern vermindern aber trotz Besserung bleibt ja eine gewisse seitliche Abweichung des Ruckgrates bestehen der Skoliosenkeim wirkt fort Daher mussen wir fur Krafte sorgen die einer Zunahme entgegen wirken

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FROM THE ORTHOPAEDIC CLINIC, VÄSTERÅS, SWEDEN
(HEAD: TORSTEN JERRE, M.D.)

"POSTERIOR APOPHYSIS" IN L IV—THE CAUSE OF NEURORADICULAR DISTURBANCE

By

BOHDAN SKOBOWYTSH OKOLOT

The so called Apophysis (intercalary bones) which is sometimes found on radiological examination and is sometimes localised to the two lowest thoracic vertebrae but usually to the anterior upper margin of the lumbar vertebrae seldom produces any subjective trouble or clinical findings. In adults it is seen on lateral X-rays as a small triangle displaced rather forward and upward from the upper edge of the vertebral body without osseous connection with the vertebra, which is somewhat blunted on its upper edge (Fig. 1). Earlier it was considered that a non uniting vertebral epiphysis was involved, that is a persistent epiphysis; later one liked to explain the phenomenon as an avulsion of the anterior part of the vertebra (therefore it was called in German literature "Abscherungen oder Abtrennungen von Wirbelkörperkanten", i.e. "Avulsions or Separations from the borders of vertebrae").

In 1928 *Schmorl* described and discussed in closer detail the above conditions. He introduced the designation apophysis instead of epiphysis in order to emphasise that this annular cartilage had nothing to do with the growth of the actual vertebral body. In German literature the apophysis was called "Randleiste". Corresponding with the German "Randleiste" *Hellmer* (1932) invented the term "limbus vertebrae" to designate the apophysis. According to *Hansson* (1926) the apophysis as a rule in girls ossifies at the ages of 11–13 and in boys from 12–15 years but a complete ossification may sometimes be delayed up to 20 to 25 years of age.

That a fracture of the upper edge of the vertebra and apophysis are two separate things was pointed out early by *Dyes* (1933), an opinion which nowadays clinicians, radiologists and pathologists hold in full

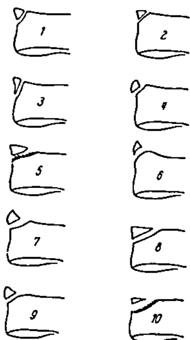


Fig 1
Various forms of anterior apophysis according to W *Leger* (1955)

agreement *Schmorl* (1928) *Junghanns* (1930) *Nieder* (1932) *Hellstadius* (1947-48) *Lindblom* (1951) *Leger* (1955) explain the arisal of anterior apophysis as owing to an impression by intervertebral disc tissue in the cancellous bone of the vertebra which slowly passes to the border of the vertebra and finally brings about an Abscherung Another opinion concerning the etiology of apophysis was put forward by *Hansson* (1926) *Joisten* (1930) *Hellmer* (1932) and partially by *Mardersteig* (1932) who thought that an ossification disturbance between the apophysis and the vertebra was involved This opinion receives a certain support from anatomic histological research by *Tondury* (1958) and *Schajowicz* (see *Tondury*)

The majority of apophysis are localised to the upper anterior vertebral border and occur mostly in one vertebra but reported cases exist where they occur in several adjacent vertebrae and also in the lower anterior border of the vertebral body

The posterior apophysis seems to be very rare and the first case of posterior apophysis i e from the posterior lower border of L IV was described by *H von Meyenburg* in 1946 *Lindblom* (1951) published two cases one radiological and one pathologic anatomical with

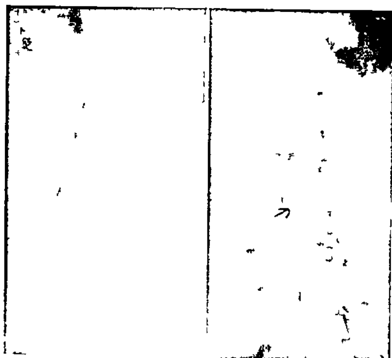


Fig 9a
Case no 1 Left posterior L IV apoph sis on lateral X ray
Right corresponding myelography

out stating from which vertebrae the apophysis came In our clinic within the course of one year no less than 3 cases of posterior apophy sis" were observed all issuing from the lower posterior part of the L IV vertebra All three patients came to us for lumbago ischias trouble and the X rays showed a dislocated fragment from the poste rior lower part of the L IV vertebra

These three cases are presented briefly below

Case no 1 J no 1068 60 A man aged 42 he had a h rt period of insignificant ach ng in his back and right calf in 1958 He denied an back trauma On 16 9 60 l n aching occured in the left calf muscles but disappeared after some hours In tead almost total paresis arose in dorsal extens rs of the left foot No back pain admittance to the Orthopaedic Clinic 27 9 60 there had again been aching in the left leg for s me days There was almost total paresis in the dorsal extensors of the t foot Patellar and Achilles reflexes were normal Lasegue po on the left side 90 n the right 75 (crossed) X rays showed quite pronounced disc degenera n L IV L V and also behind the posterior l wer c rner of L IV vertebra was an fied body about 7 mm high and 5 mm thick It seeme l t be a ulsed from the

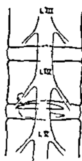


Fig 2b

Case no 1 Diagram position of the apophysis of the L V nerve root and of the disc rupture at operation

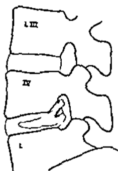


Fig 2c

Case no 1 Diagram tipped apophysis and disc rupture

posterior lower border of the L IV vertebra Tomography showed no destruction within L IV The bony body behind the vertebra s posterior lower border was a few cms wide from side to side On a level with the caudal part of L IV vertebra myelography revealed a marked bulge in the subarachnoid space This bulge was strikingly long and extended from the middle of L IV vertebra across the intervertebral disc to the upper part of L V vertebra In the centre of this bulge lay the ossified body described above L V s nerve root was displaced medially backward (Fig 2a) Owing to the severe aching of the left leg and the marked paresis of the dorsal extensors of the large toe and foot operation was performed on 3 10 60 with hemilaminectomy on L IV on the left side The L V root was found severely compressed and adhering to its surroundings A pronounced protusion of the disc lying below was found. The disc was incised and large masses of degenerated disc tissue in all 4 ccs were taken out After the disc was evacuated it was also observed that the nerve root was pressed laterally by quite a hard tissue which on closer inspection proved to consist of the avulsed piece of bone observed on X ray The whole of the posterior lower corner of the L IV vertebra was dislocated backward but its cranial part was firmly attached to the remainder of the vertebra with a connective tissue similar to pseudarthrosis or an epiphyseal line The L V root was brought round medially and a large free lying disc sequestrum which measured 1 5 cms was discovered (Fig 2b) This sequestrum had moved from the disc between the dislocated vertebral border and the vertebra itself in a direction from below and upward (Fig 2c) During its passage the disc sequestrum had lifted up the posterior apophysis so that the L V root had jammed between the avulsed piece of bone which lay medially-caudally and the disc sequestrum which lay ventrally cranially and laterally The dislocated piece of bone was successfully removed in certain places however it was very firmly attached to the vertebra and connected to it by fibrous tissue similar to pseudarthrosis tissue The dislocated piece of bone made a marked transverse impression on the dura PAD of the dislocated bone showed lamellar bone proliferative hyaline cartilage tissue and periosteal connective tissue The preparation was quite free from signs of inflammation The post operative course was without complication The patient had no more aching in the left leg The paresis sl wl

receded He was discharged on 15 3 61 and on reexamination the 16 3 62 he had no trouble from back or leg Laseque was neg bilaterally but there was slight paresis on dorsal extensors of the left foot After discharge the patient had worked on heavy line work to the fullest capacity

Case no 2 J no 182/61 A man aged 19 Previously healthy He had done heavy agricultural work. He had never had back trouble and denied firmly any back trauma. He came on the 13 2 61 because of persistent aching on the exterior aspect of the whole of the left leg The trouble was 2 weeks old with successively increasing pain On clinical examination there was severely restricted forward bending throbbing pain above the lumbar back Lasègue pos on the left side was 30 crossed pos on right side was 60 Achilles reflexes were absent on the left side Otherwise neurologically O Radiological examination including tomography and myelography showed a large defect on the posterior lower part of L IV and behind this defect a large fragment dislocated from the vertebra about 10 mm high and 5 mm thick The dislocation was estimated at fully 1 cm backward The dislocated posterior border of the vertebra made a bulge into the subdural space the size of a grape (Figs 3a 3b) Owing to the marked lumbago ischias trouble of the patient and the X ray findings he was operated on the 22 2 61 with total laminectomy on L IV On operation a considerable bulge was found cranially to the exit of the S 1 root on the left side this bulge passed like a rampart beneath the dura towards the right

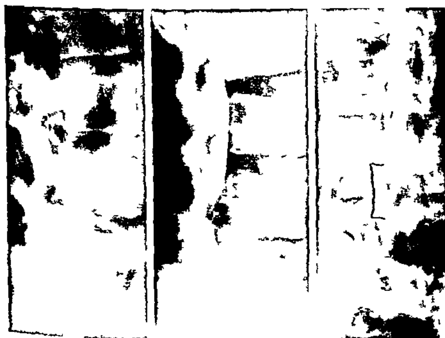


Fig 3 a
Case no 2 Localisation of posterior L IV X ray and myelograph



Fig 3b

Case no 2 Tomographic picture of the apophysis

side (Fig 3c) This corresponded very well with the X ray finding of the posterior apophysis localised to lower posterior part of L IV On the left side caudally of the apophysis a distinct disc rupture was palpated which extended medially in under the dura Neither the disc rupture nor the lateral end of the apophysis reached the L V root which looked quite normal macroscopically The disc was incised and fully 1 cc of degenerated disc tissue was taken from it On the right side of the dura the disc also bulged somewhat but not so much as on the left the disc was incised here too and fully ¼ cc of degenerated tissue was removed The posterior apophysis was dissected free Its lower end was tipped backward while its upper end was firmly attached to the rest of L IV vertebra by a tough connective tissue (Fig 3d) This connective tissue extended across the whole width of the apophysis Macroscopically it looked like an epiphyseal line

Since the apophysis was very large and firmly attached to the vertebra total removal was rejected Instead only the posterior part which pressed against the dura throughout its width was exstirpated After this intervention no more pressure was present against the dura The postoperative course was completely free from complication The aching in the left leg disappeared completely The patient was discharged 16 4 61 The last follow up was on the 3 8 61 There was no ache the status of the back was completely normal Lasegue was neg Only slight reduction of the Achilles reflexe on the left side The patient had been employed the whole summer on heavy agricultural work



Fig 3c
Ca e no 2 Diagram position of apo ph is an l di c rupture at operation

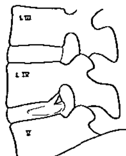
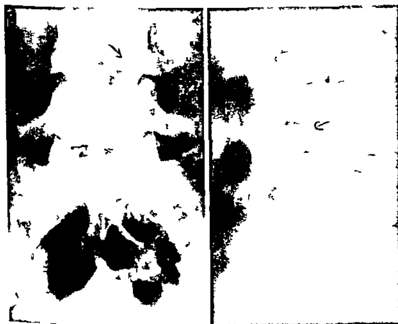


Fig 3 I
Case n 2 Diagram tipped apophy i and di rupture

Case no 3 J no 854 61 A woman 92 years of age Pre i usl health She denied back trauma She had suffered back trouble for 2 years in the form of tiredness and achin in the lumbar back sometimes radiating towards the right hip and right leg n the posterior aspect of the thigh and on the same a pe t of the alf to ard the right heel In the summer of 1961 there was considerable wors ning when she helped her husband to build a summer cottage She went to the local doct r wh made the diagnosis of lumbag ischias and remitted the patient t the Orthopaedic Clinic



F j 4a
Ca e n 3 Radiolog l ali ati n f po terior apophysis



Fig 4b
Case no 3 Radiology with myelography lateral picture with localisation of apophysis

On examination at the beginning of August 1961 the status was completely negative but X rays showed on the right behind the posterior lower vertebral border of L IV a calcification the size of a peanut and of the same appearance as the posterior apophysis described above (Fig 4a) The intervertebral spaces were normal Apart from the previously described posterior apophysis in the lower part of L IV myelography showed a moderate bulge in the contrast medium on a level with the intervertebral disc L IV–L V The bulge was especially pronounced on the lateral picture but not on the frontal picture (Fig 4b) There were no certain signs of disc ruptur Since the patient had no signs of root compression on examination and was completely free from trouble no indication for operation was found

CONCLUSIONS

In all these cases the diagnosis of posterior apophysis from L IV appears to be completely certain The possibility that instead a pseud arthrosis might be involved can be rejected since

1) isolated fresh fractures of this type are unknown and as far as

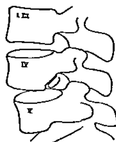


Fig 5
Diagram of posterior apophysis of L IV vertebra

one can understand impossible without simultaneous injury to arches or intervertebral joints

2) these three cases radiologically and anatomically are fully similar to those quite common anterior apophysis which are not now considered to be traumatically conditioned

3) in spite of a particularly thorough questioning of the patients it was not possible in any single one of these cases to discover any adequate trauma

Whether it is an ossification disturbance or like *Schmorl s* nodules a dissecting disc mass detaching the posterior corner of L IV or whether both factors contribute to the arisal of the posterior apophysis is difficult to judge The level and straight connections similar to epiphyseal lines which were observed at the 2 above operations between the vertebra and the cranial part of the apophysis (Fig 5) and also the pathological anatomical examination of the operative preparation in the first case argue in my opinion in favour of ossification disturbance

As I understand it the incompletely ossified area formed a corpus minoris resistentiae and an impression by degenerated intervertebral disc tissue in this area brought about an avulsion of the apophysis and produced neuroradicular symptoms

SUMMARY

The author describes three cases of posterior apophysis originating in the posterior lower part of the L IV vertebra

In the first case the apophysis caused an L V syndrome in the second case an S I syndrome and in the third case a history of lumbago-ischias trouble but without clinical findings on examination

At operation disc rupture was encountered both in the first and in the second operation case [1]

RESUME

L auteur decrit trois cas d apophysite posterieure provenant de la partie inferieure de la 4eme vertebre lombaire

Dans le premier cas l apophysite a provoque un syndrome de la 5eme vertebre lombaire Dans le deuxieme un syndrome de la 1ere vertebre sacree et dans le troisieme cas des troubles anamnestiques de lumbago sciatique mais sans trouvailles cliniques a l examen du cas

A l operation on a trouve une rupture du disque aussi bien dans le 1er que dans le 2eme cas

ZUSAMMENFASSUNG

Der Verfasser beschreibt drei Fälle von ruckwärtiger Apophysitis die sich vom hinteren kaudalen Teil des 4 Lendenwirbels entwickelte

Im ersten Falle rief die Apophysitis ein L V Syndrom hervor im zweiten Falle ein S I Syndrom und im dritten anamnestisch Lumbo-Ischiasbeschwerden jedoch ohne klinischen Befund anlasslich der Untersuchung Bei der Operation wurde ein Zwischenwirbelscheibenbruch im ersten und zweiten Falle gefunden

REFERENCES

Dyes O Die Randleistenfractur des Wirbels Arch f Orthop u Unfall Chir 3 297 1933

Hansson R Some Anomalies Deformities and Diseased Condition of the Vertebrae Acta chir scand *60* 309 1926

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[1] Since the above article was completed another case of posterior L IV apophysis has been observed at the Clinic here It is reported briefly below

A previously healthy schoolboy aged 14 He has had increasing trouble in the last 2 years in the form of tiredness and sometimes aching in the lumbar back after athletics or fairly heavy lifting No case history of back trauma The aching does not radiate towards the lower extremities The back has increased its aching in recent months He came to the Clinic for back trouble Clinically the status is completely normal

Radiology shows slight Morbus Scheuermann a low disc between L IV L V and also an apophysis from the posterior lower part of L IV On X rays the above apophysis was measured at about 3 mm high and 6 mm thick It extends about 6 mm into the spinal canal calculated from a plane through the posterior border of the vertebral body The case is under observation and no orthopaedic measures have yet been undertaken

Hellmer H Rontgenologische Beobachtungen uber Ossifikationsstorungen im Limbus vertebrae Acta radiol *13* 483 1932
H llstadius A Paradiscal defects Acta orthop scand *17* 50 1947–48
H llsta l us A Anterior Paradi cal defects Acta orth p scand *18* 377 1949
Joisten Chr Uber persistirende Apoph sen an der Lendenwirbelsaule Arch f Orthop u Unfall Chir *28* 622 1930
Junghanns H Die Randleisten der Wirb lkorper (Wirbelkorperepiph en im Rontgenbild Fortschr a d Geb d Rontgenstrahlen *42* 333 1930
L g r W Hat die kantenabtrennung der Wirbelkorper eine klini he Bedeutung Arch f Orthop u Unfall Chir *47* *159* 1955
Lindblom K Dissecting transosseus ruptures of intervertebral dises Acta radiol *36* 12 1951
Lgon E Uber Bruche von Epiph sen der Lenden virt elkorp r im Jun ling alter Fortschr a d Geb d Rontgenstrahlen *38* 376 1928
Lgon E & Marum G krankheiten der Wirbelk rperepiph sen F t chr a d Geb d Rontgenstrahlen *44* 498 1931
Mar lersteig K Zur Frage der persistierenden Wirbelkorperapoph en F rt h r a d Geb d Rontgenstrahlen *46* 441 1932
v M genburg H Uber „Abtrennung der hinteren Wirbelk rperkante als U r a he von Ischias Radiologia Clinica *15* 215 1946
Nedn r F Zur Kenntnis der normalen und path l gischen Anatomie der Wirbelkorperrandleiste Fortschr a d Geb d Rontgenstrahl n *46* 6 8 1932
Schmorl G Uber knorpelknotchen an den Wirbelbandscheiben F t chr a d Geb d Rontgenstrahlen *38* 265 1928
Schm rl G Die Pathogenese der juvenilen k ph se F rts hr a d Geb d Rontgenstrahlen *41* 359 1930
Schmorl G Beitrage zur pathologis hen Anatomie der Wirbelb nd heiben und ihre Beziehungen zu den Wirbelkorpern Arch f Orth p u Unfall Chir *29* 389 1931
Schmorl G & Junghanns H Die gesunde und kranke Wi bel ule im R ntg n bild 26–27 59–63 Leipzig 1932
Tön lurg R Entwicklungsgeschichte und Fehlbildungen der Wirbel ul Stuttgart 1958

FROM THE ORTHOPAEDIC CLINIC BORAS
(HEAD DOCENT FOLKE STAHL)

HOW OFTEN DO THE NEUROLOGICAL SIGNS DISAPPEAR AFTER THE OPERATION OF A HERNIATED DISC?

By

BERTIL KNUTSSON

This problem received attention from *Waris* in 1948 He reported on 56 *patients in whom the Achilles tendon reflex had disappeared com*pletely and found on review 1 to 5 years after the operation that the reflex returned to normal strength in 12 (21 4 %) In 5 cases (8 9 %) a weak Achilles tendon reflex was demonstrable while in 39 (69 6 %) the loss of the reflex was permanent

The Achilles tendon reflex was weak in 18 cases before the operation in 2 (11 1 %) of them the reflex could not be elicited at all at the review 8 (44 4 %) still had a weak reflex and in 8 (44 4 %) it was normal

Waris found also that in 2 cases a complete paresis of the dorsal extensors of the great toe had disappeared by the re examination 15 patients with weakness of the extensors of the great toe were followed up and in 10 (66 6 %) the extensors recovered normal strength and in 5 (33 3 %) slight weakness persisted

As to impairment of sensibility *Waris* stated that the symptom persisted unchanged in 38 7 % in his material of 137 patients who had the symptom before operation

At the review he observed no atrophy except in those cases with definite muscle weakness

2 years earlier (1946) *Friberg & Hirsch* reviewed 44 patients who had been operated upon at least 5 years previously They found regression of the impairment of sensibility in 42 4 % but they never found any recovery of the Achilles tendon reflex

One of them (*Friberg* 1941) had found on review of 24 patients that in 3 of them in whom the patellar reflex was weak *before* the operation this was normal at the review Two of these three patients showed a

weakened Achilles tendon reflex before operation but in those patients the reflex had also become normal by the time of review In one patient the Achilles tendon reflex was also normal at the review instead of weakened before operation *Friberg* thus observed recovery of a weakened reflex in 4 patients

In 1946 *Senning & Sjoqvist* reported recovery of the Achilles tendon reflex after complete loss in 11 cases They also found that paresis of the extensors of the great toe usually disappeared within a very short time after operation but in some few cases it persisted for many years

Three years later (1949) *Rowig* wrote It is emphasized that neurological changes such as disturbance of the motor and sensory systems and also change in reflexes due to root lesion may persist for years after the compression has been removed

Another orthopaedic surgeon *O Connel* (1950) found persistent reflex changes in 62 % persistent muscular weakness in 6 6 % and persistent impairment of sensibility in 30 % and atrophy in 8 4 % at review

The literature for the rest contains very scanty data on persistence or disappearance of neurological signs and symptoms The first to discuss this point were *Alajouanine & Petit Dutaillis* (1913) and the claimed that one should not except too much of the possibilities of regeneration The same year however *Towne & Reichert* described a case with loss of Achilles tendon reflex and marked impairment of sensibility and 16 months after operation the reflex and sensibility was normal *Howard Brown* (1937) and *Spurling Mayfield & Rogers* (1939) also presented 7 and 6 patients respectively where a disappeared reflex returned to normal after operation

TABLE 1

	Before operation		At the review		
	Weakened	Absent	Normal	Weakened	Absent
Achilles tendon reflex		40	1	5	34
	69		18	40	11
Patellar reflex		4			4
	29		1	28	
	Paresis	Paralysis	Normal	Paresis	Paralysis
Strength in the extensor of the great toe		13	3	4	6
	110		84	26	

As it would seem the data among this question in the literature are very scanty and contradictory.

Therefore the author has made a fairly thorough examination of the patients (who were operated in a 2 years period) before and 1 year after the operation.

The results are summarized in table 1.

It is clear from table 1 that of 40 patients with loss of the Achilles tendon reflex before operation the reflex was still absent at the review in 34 (85 %), while in 5 (12.5 %) it had returned but was still weak. Only in 1 patient (2.5 %) had the reflex returned to normal.

In 69 cases the Achilles tendon reflex was weakened before operation, and at the review the reflex was still weak in 40 (58 %), in 11 (15.9 %) it could not be elicited, and in 18 (26.1 %) it had returned to normal.

As to the patellar reflex it was found that in 4 patients in whom the patellar reflex was absent before operation, it was unchanged at the review.

Of the 29 patellar reflexes, which were weak before operation, one was normal at the review, while the 28 were unchanged.

13 of the patients had paralysis of the extensors of the great toe before operation. At the review 6 (46.2 %) still had paralysis, 4 (30.8 %) showed weakness of the muscle strength, and 3 (23 %) had returned to normal strength of the toe.

84 patients (76.4 %) of 110 with weakness of the gross strength of the extensors of the great toe before operation had at the review normal strength, while it was still reduced in the remaining 26 (23.6 %).

In table 2 you will find in those cases where the neurological signs changed after operation how long the symptoms had persisted before operation was done.

Loss of sensibility was at the review noted to remain in 67.2 % and muscular atrophy in 75.6 %.

It must thus be concluded that with the exception of weakness of the dorsal extensors of the great toe, the neurological signs persist to a high degree unchanged at least one year after the removal of the root compression.

A comparative study was made with the electromyographic findings, and therefore all these patients were examined electromyographically (Method, see *Knutsson* 1959) before the operation and one year after the operation. And thereby it was found that at the preoperative examination 185 patients showed electromyographic changes shown

root compression against only 42 (22 7 %) after operation and in [illegible] ([illegible] %) there were persisting electromyographic changes in a single muscle The electromyographic findings thus tend to disappear in a greater percentage than the clinical neurological signs after the removal of a root compression

TABLE 2

Before operation Neurological sign	After operation Neurological sign	Operation finding	Duration of symptoms
Achilles tendon reflex absent 40	Achilles tendon reflex normal 1	Herniated disc	4 months
	Achilles tendon reflex weakened 5	Herniated disc	[illegible] m mean 3 m
Achilles tendon reflex weakened 69	Achilles tendon reflex normal 18	Positive disc changes 1[illegible]	1 20 m mean [illegible]8 m
		Negative expl 1	3 m
Patellar reflex weakened 29	Patellar reflex normal 1	Herniated disc	8 m
Paralysis of the extensors of the great toe 13	Normal strength in the extensors of the great toe 3	Herniated disc	3 m mean 3 m
	Paresis of the extensor of the great toe 4	Herniated disc	1 4 m mean 2 m
Paresis of the extensor of the great toe 110	Normal strength in the extensor of the great toe 84	Positive disc change 80	1 10 m mean 4 m
		Negative expl 4	1 5–4 m mean 8 m

SUMMARY

An account of a review of patients one year after the operation for herniated disc syndrome with special reference to the disappearance of the clinical and electromyographic signs is given It was found that the electromyographic changes regressed considerably after operation while the clinical neurological signs with the exception of weakness of the great toe persisted in a high degree

RESUME

Il est rendu compte de l examen de malades un an apres qu ils aient ete operes pour un syndrome d hernie discale en se referant particulierement a la disparition des signes cliniques et électromyographiques Il a ete decouvert que les modifications electromyographiques diminuent considerablement apres l operation tandis que les signes cliniques neurologiques a l exception de la faiblesse dans le gros orteil persistent a un haut degre

ZUSAMMENFASSUNG

Ein Bericht uber die Durchuntersuchung von Patienten ein Jahr nach der Operation wegen Scheibenprolapssyndromes unter besonderem Hinweis auf das Verschwinden klinischer und elektromyographischer Zeichen wird gegeben Man fandt dass die elektromyographischen Veranderungen nach der Operation bedeutend zuruckgingen wahrend die klinisch neurologischen Zeichen mit Ausnahme der Schwäche der grossen Zehe zumeist bestehend blieben

REFERENCES

Alajouanine T & Petit Dutaillis D La nodule fibrocartilagineux de la face postérieure des disques intervertebraux Presse med *38* 937–945 1930

Brown H Enlargement of ligamentum flavum cause of low back pain with sciatic radiation J Bone & Joint Surg *20* 325–338 1938

Friberg S Low back and sciatic pain caused by intervertebral disc herniation Acta Chir Scand suppl 64 85 1–114 1941

Friberg S & Hirsch C On late results of operative treatment of intervertebral disc prolapses in the lumbar region Acta Chir Scand *93* 161 168 1946

Knutsson B Electromyographic studies in the diagnosis of lumbar disc herniations Acta Orthop Scand *28* 290–299 1959

O Connel J E A The indication for and results of the excision of lumbar intervertebral disc protrusions A review of 500 case Ann Roy Coll Surg Engl *6* 403–412 1950

Rot ig G Rupture of lumbar discs with intraspinal protrusion of the nucleus pulposus Acta Chir Scand suppl 144 1949

Senning A & Sjoqvist O Senresultaten vid diskbråck En efterundersokning av 400 opererade fall Nord Med *34* 1128–1129 1947

Spurling G R Mayfield F H & Rogers J B Hypertrophy of ligamenta flava as cause of low back pain J A M A *109* 928 933 1939

Towne F B & Reichert F L Compression of lumbosacral roots of spinal cord by thickened ligamenta flava Ann Surg *94* 327 336 1931

Waris W Lumbar disc herniation Acta Chir Scand suppl 140 1949

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PROCESSED CORTICAL BONE FOR INTERNAL FIXATION IN LUMBOSACRAL ARTHRODESIS

An Application of the Distraction Impaction Principle to Increase the Intervertebral Canal and Disc Spaces

By

MARSHALL R URIST M D
U S A

Surgeons everywhere value the works of the distinguished professors of orthopaedics *Gunnar Wiberg & Sten Friberg* on the subject of low back pain *Wiberg* (16 29–32) described the nerve supply of the intervertebral discs and results of laminectomy for lumbar protrusions and *Friberg* (11–14) analyzed the pathogenesis and surgical treatment of congenital and acquired defects of the lumbosacral spine These two investigators have dealt with all the important questions that are under intensive investigation in orthopaedic clinics everywhere in the world The following three questions are of great interest at this time when many patients are appearing with degenerative joint disease and large bone defects following laminectomy Is it possible to restore the intervertebral canal and disc spaces and produce arthrodesis at the same time? Assuming an arthrodesis relieves pain what is the surgical procedure that will *succeed in the highest percentage of patients? Can* internal fixation be obtained by mortised implants of bone?

A new material has recently been introduced for spinal fusions This is designed to provide guaranteed sterility minimal antigenicity unlimited period of storage and ready availability In previous investigations such material was described as collapatite a derivative of bone

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consisting of collagen with its apatite mineral to be used as a substitute for metal for internal fixation of fractures The surgical procedure in which processed bone is used is similar to that advocated by *Friberg* on the basis of the end result study by *Unander Scharin* (1950) this consists of iliac autografts between spinous processes intervertebral arches and joints except that an implant in the form of an "H block is added for internal fixation The block is not a substitute for warm viable autogenous graft but serves as a physical chemical mechanical scaffold

METHODS AND CASE MATERIAL

The method of processing of homogenous or heterogenous cortical bone to retain the collagen and apatite and exclude as much as possible of the extrafibrillar and intracellular protein described in a previous report (26 27) was employed in the first 10 cases Bovine heterogenous bone (*Boplant Squibb*) prepared by new and improved methods by procedure of Dingwall and his associates was implanted in the succeeding 18 cases This processed bone is now under investigation in all kind of experimental animals and orthopaedic cases (*Anderson et al* 1962 *Bassett et al* 1962)

Twenty eight patients with severe low back pain caused by degenerative disc and joint disease or spondylolithesis were treated either *per primum* or as a secondary procedure following removal of the nucleus pulposus by surgical fusion of the posterior elements of the lumbosacral region In general the method consisted of

1) midline dorsal incision for decortication or fish scaling of the lamina as in a classical Hibbs fusion
2) lifting of the dorsal cortex of the facets
3) matchstick autogenous grafts into 1 5 mm transarticular drill holes through the center of the facets while the spine is in acute flexion
4) carving a groove in the base of the spinous processes including the lamina of *the first sacral vertebra*
4) transfer of fresh autogenous bone from the crest of the ilium by extending the dissection lateralward along the lumbosacral fascia through the same incision
6) placement of a carpet of strips and a thin H shaped plate of iliac bone between the lamina of the lower lumbar vertebra and the sacrum
7) implantation of a block of processed cortical bone (*Boplant*) mortised as close as possible to the base of the spinous processes with the spine in flexion and with the aid of lamina spreading forceps to produce maximum distraction or separation of posterior elements of the vertebra
8) early ambulation in a firm corset

To avoid weakening and possible fracture of the spinous processes the notches are prepared as close to the base as possible and only the minimum amount of bone is removed with a small rongeur When the thick block (0 8 cm) of processed cortical bone is placed above the thin block (0 15 cm) of fresh autogenous bone there

TABLE 1

Summary of 28 patients with internal fixation with blocks of processed bone for arthrodesis of the lower lumbar spine

Name	Age	Diagnosis	Date of operation	Site of arthrodesis	Current status
A F H	[illegible]	Old laminotomy	[illegible] 17 59	L — S_1	Pain free
J K	33	Spondylolisthesis	4 14 59	L_4 L S_1	Pain free
V R	69	Spondylolisthesis spondylosis scoliosis	5 25 59	L_3 L_4	Unimproved
C R	40	Old laminotomy	18 59	L_4 L S_1	Improved
C L	43	Laminotomy arthrodesis *per primam*	9 2[illegible] 59	L_4 L –S_1	Pain free
A K	40	Old laminectomy	11 1 59	L_4 L S_1	Improved
L N	36	Old bilateral laminectomy	11 17 59	L_4 L S_1	Improved
D A	50	Old laminotomy spondylosis	12 16 59	L_4 L S_1	Improved
J M C	50	Spondylolisthesis	[illegible] 1 60	L_4 L S_1	Unimproved und infect
B B	6[illegible]	Old laminectomy	[illegible] 2 60	L_3 L_4 S_1	Pain free
J F R	4[illegible]	Old laminectomy	2 4 60	L_4 L –S_1	Pain free
H W	[illegible]8	Laminotomy and arthrodesis *per primam*	3 [illegible]9 60	L_4 L S_1	Pain free
H I	4[illegible]	Old laminectomy and arthrodesis L S_1	5 31 60	L_4 L	Unimproved
B B	48	Old laminotomy	5 10 60	L_4 L S_1	Unimproved
F F	40	Laminotomy *per primam* spondylosis	6 30 60	L_4 L S_1	Unimproved
D M C	44	Laminotomy and arthrodesis *per primam*	9 7 60	L_4 L S_1	Pain free
R H	33	Laminotomy and arthrodesis *per primam*	11 [illegible]8 60	L S_1	Pain free
T C	[illegible]9	Laminotomy and arthrodesis *per primam*	12 8 60	L_4 L S_1	Pain free
F M	37	Laminotomy and arthrodesis *per primam*	[illegible] 16 61	L_4 L S_1	Pain free
[illegible]	37	Old laminotomy L_4	5 [illegible] 61	L_4 L S_1	Improved but not pain free
M A	[illegible]3	Laminotomy and arthrodesis *per primam*	5 18 60	L S_1	Pain free
C S	41	Laminotomy and arthrodesis *per primam*	[illegible] 2[illegible] 61	L_4 L S_1	Too recent to evaluate
A W	2[illegible]	Laminotomy and arthrodesis *per primam*		L_4 L S_1	Too recent to evaluate

TABLE 1 (cont)

Name	Age	Diagnosis	Date of operation	Sites of arthrodesis	Current status
J F	46	Laminotomy and arthrodesis *per primam*	8 28 61	L_4 L_5–S_1	Too recent to evaluate
T B	1	Spondylolisthesis I	11 10 61	L_4 L_5 S_1	Too recent to evaluate
J L	34	Laminotomy and arthrodesis *per primam*	1 11 62	L_5 S_1	Too recent to evaluate
C B	42	Laminotomy and arthrodesis *per primam*	2 8 62	L_4 L_5 S_1	Too recent to evaluate
R F	36	Laminotomy and arthrodesis *per primam*	2 9 62	L_5 S_1	Too recent to evaluate

TABLE 2

Summary of 28 lumbosacral fusion operations

Diagnosis	No	No pain free	No improved	No unimproved	Fail
Spondylolisthesis	4	2	1	1	25
Old laminectomy	4	2	0	2	50
Old laminotomy	6	1	4	1	16
Laminotomy and fusion *per primam*	7	6	0	1	14
Laminotomy and fusion *per primam* (too recent to evaluate)	7	–	–	–	

appears to be excellent although probably not absolute internal fixation When the spinous process of the first sacral vertebra is underdeveloped or absent as in patients with spondylolisthesis a prong or groove is sculptured out of the lamina of the second sacral vertebra to engage the blocks

RESULTS

Table 2 summarizes the short term results in 28 consecutive patients presenting both complicated and uncomplicated problems The number of cases is too small and dissimilar to evaluate the treatment but the effects of the method are interesting The blocks sustained the spaces of the posterior portion of the disc and the intervertebral canal An increase of as much as one millimeter may occur without any demon

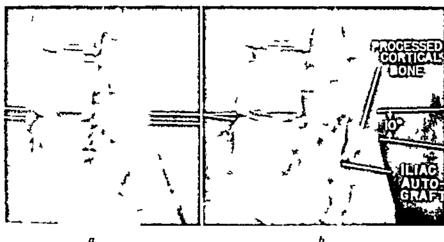


Fig 1a Lateral view radiograph of the lumbosacral spine of C L a 43 year old woman with degenerative joint and 4th lumbar intervertebral disc disease Note the circumferential bony lip at the attachment of the annulus fibrosis and the anterior longitudinal ligament

Fig 1b Radiograph of the case shown in Fig 1a illustrating the placement of the autogenous iliac bone and processed bone blocks and the enlargement of the intervertebral canal and the posterior intervertebral disc space 2 weeks after the operation The angle of elevation in the vertebral body is from 0 to approximately 10

strable change in the radiographs In some cases it is clearly visible that the block can spread open or increase the posterior space of the intervertebral disc as well as enlarge the intervertebral canal and at the same time produce a solid painless arthrodesis of the spine between the fourth lumbar vertebra and the sacrum (Figs 1 A to F) The fifth lumbar space generally is unchanged but in patients in which the joints are freely movable spreading occurs at the fourth lumbar interspace The disc spaces and the joints of the first second and third lumbar vertebra do not appear to respond or decrease in thickness

The radiographic appearance of the blocks of processed bone observed at various intervals from 1 to 3 years after the operation is the same as that of autogenous or homogenous *cortical* bone Where the implant becomes incorporated in new bone the sharp corners of the block become round and irregular in outline (Fig 1F)

The early results of the operation show an interesting trend in the following direction Patients with spondylolithesis or recovering from old laminectomy operations may or may not obtain relief of backache



Fig 1c
Radiograph of the same case as shown in Figs 1a and 1b showing sustained distraction and fusion of the posterior elements of the lumbosacral spine two and one half years after operation

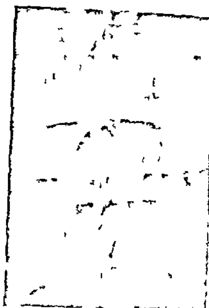


Fig 1d
Radiograph in the anteroposterior view of the case shown in Figs 1a to 1c The 4th lumbar intervertebral disc space is markedly less than that of the 3rd and there is a bony lip on the right superior rim of the 5th lumbar vertebral body

Patients with laminotomies particularly those having an arthrodesis *per primam* or at the time of excision of an intervertebral disc have a relatively good outlook for either cure or improvement *Bosworth* (1948) emphasized the fact that the percentages of solid fusion were high in the single interspace fifth lumbar operations and relatively low in procedures that include the fourth lumbar interspace In the series listed in Table 1 in which 23 of the 28 cases extended from fourth lumbar vertebra to the sacrum the early results were 14 to 16% symptomatically unimproved patients It is necessary to perform a year follow up examinations to compare these early results with end results statistics reported in the literature (3 7 17 21) Some patients with a pseudarthrosis will be relieved of symptoms while others may not In the patients that are unimproved it has been assumed the re-exploration is the only positive way to demonstrate that a pseudarthrosis does or does not exist (*Bosworth* 1948) One case (J McG) a man with an unexplained postoperative wound infection required reopera



Fig 1e

I toperative radiograph of the bl cks of pr xes ed I ne c r ce llapatite (*Boplant* Squib) between the 4th and 5th lumbar spin us pr ce ses h wn in Fig 1b



Fig 1f

Radiograph f the case sh wn in Fig 1a to 1e tw and ne half years after operation N te the re rption f the c rners of the b1 ck between the 4th an l 5th lumbar vertebra The pr c ed b n is resorbed m re l wl than underlying aut gen us b ne grafts that are een in Fig 1b N te the lliterati n f the intervertebral j int

tion the processed bone blocks were unfused and enveloped in infl am matory fibrous connective tissue The implants were removed an inter tr insverse process arthrodesis will be attempted at some future date

DISCUSSION

The capacity of an implant to produce arthrodesis is determined by several factors The first and most import int is the osteogenetic acti vity of the host bed (*Urist et al* 1953 1958 1960) The second is fresh autogenous cancellous bone with the capacity to produce an outgrowth of osteogenetic cells (*Abbott et al* 1947) (*Urist & McLean* 1952) The third is the adverse effect of donor tissues that evoke immune responses from the host The literature on the third factor with specific refe

rence to bone has appeared for the most part in recent years (*Burwell & Gowland* 1962) *Billingham, Brent,* and *Medewar* 1956 and *Medewar* 1959 proposed that antigens appeared in two forms H antigens which are relatively stable amino acid complexes and provoke the formation of humoral or serum antibodies and T antigens which are relatively labile DNA protein complexes and evoke the production of cell bound antibodies Transplantation immunity is mediated by antibodies produced by T antigens and carried by lymphoid cells (*Medewar* 1959) The chief source of T antigen from homogenous iliac cancellous bone is the DNA of the chromosomes of the nucleated cells of the red bone marrow (*Burwell & Gowland* 1962) Quantitatively there is much less antigen in cortical bone (*Weinberg et al* 1959) after it has been scraped free of periosteum and marrow The osteocytes buried in the interior of cortical bone retain their nucleoprotein and are protected from contact with antibody bearing lymphoid cells

Homogenous or Heterogenous Processed Bone The removal of the non collagenous especially nucleoprotein from homogenous or heterogenous bone may be assumed to quantitatively reduce the capacity of the donor tissue to evoke immune responses In 1934 when very little was know about tissue antigen in order to produce a readily available source of bone *Orell* processed calf bone by defatting in acetone and extracting proteins including collagen with salt solutions and warm potassium hydroxide and named it *Os Purem* In 1952 *Orell* abandoned *Os Purem* because of its slow osteogenetic activity preferred a granulate of whole bone frozen at -190 and recommended that the latter be used in combination with metal or cortical bone for fixation

Local Physiologic and Technical Factors Autogenous bone grafts in liberal quantity are absolutely essential for a strong arthrodesis but local factors such as immobilization and contact compression with the host bed are very important While stored homogenous and heterogenous bone often succeed in fusions of the dorsal spine in children failure has been reported in a high percentage of cases in the low back in adults After growth ceases even a fresh autogenous bone graft sometimes develops a pseudarthrosis *Barr* (1959) observed that "There is an obvious need for better techniques of fusion the incidence of pseudarthrosis is much too high Technical factors explain the appearance of a pseudarthrosis in some cases In most instances a combination of the following factors are probably involved

a) insufficient attention to the work of "fish scaling of the lamina

b) too much necrotic or missing bone in the host bed to produce osteogenesis
c) insufficient immobilization or failure to provide contact compression between the donor tissue and the host bed
d) insufficient osteogenetic tissue or autogenous bone or supply of the proliferating cells that in an adult individual is essential for all operations to bridge a bone defect

T antigens produced in the course of resorption of the donor cells can lead to envelopment of the tissue in the lymphoid cells that carry cell bound antibodies and cause rejection of homogenous or heterogenous bone

Immobilization Impaction and Distraction The lumbosacral region requires a plaster bed including both hips to produce total immobilization To avoid prolonged periods in bed internal fixation in the form of interfacet screws or paraspinous process plates have been advocated by some surgeons but rejected by others who observed late complications such as necrosis and dissolution of bone tissue or foreign body problems in instances of pseudarthrosis Immobilization by means of bone impacted between the spinous processes was described by *Gibson* (1931) *Bosworth* (1942) *Breck & Basom* (1942) first with autogenous tibial cortex and then with iliac bone removal of cortical bone from the tibia caused too many fractures and some of the grafts behaved like sequestra Nevertheless *Leikkenen* (1959) reported the use of double grafts tibial plus iliac bone but he implanted the strips along side the spinous process The distracting block method aims to restore or enlarge the nerve and disc spaces during the period of fusion of the posterior elements and at the same time provides immobilization by impaction

Biopsy There was one wound infection reoperation and recovery of the implant for microscopic study The processed bone was encased in fibrous scar on all sides and contained no ingrowth of new bone from the host In a previous study in which pegs were used for internal fixation of a fracture of the hip it was noted that the interstices of the processed bone were invaded by osteogenetic tissue and attached to the host bone through the deposition of cement substance (*Urist* 1960)

Osteogenesis Further improvement in the statistics of spinal fusion may depend upon new progress in basic research on the physiologic mechanisms of osteogenesis At the present time autogenous bone can

be considered a graft in the sense that cells survive transplantation but it is misleading to describe preserved bone as a graft. The success of preserved bone, especially after it is processed by extraction, depends entirely upon the osteogenetic power of the cells in the host bed.

SUMMARY

1. Processed homogenous or heterogenous cortical bone was successfully employed in the form of an H block, in combination with iliac autogenous, for internal fixation and spreading of the posterior vertebral arches for arthrodesis of the lumbosacral spine.

2. In some patients with freely movable intervertebral joints the two layered implant of autogenous iliac and processed cortical bone can enlarge the intervertebral disc and canal spaces and at the same time provide internal fixation for an arthrodesis operation.

3. Processed cortical bone, either homogenous or heterogenous, is a well tolerated relatively inert material that is superior to metal when it becomes incorporated in the host skeleton.

RÉSUMÉ

1. Du tissu osseux periostique homogène et hétérogène a été employé avec succès sous la forme d'un bloc en H pour la fixation interne et l'extension des arcs vertébraux postérieurs dans l'arthrodèse de la colonne lombaire et sacrale.

2. Le bloc en H était un complément à une opération de fusion inter facettaire, interlaminaire et interspinale avec de l'os iliaque autogène.

3. Les deux couches implantées, os iliaque autogène et tissu osseux periostique, peuvent simultanément élargir le disque intervertébral et l'espace du canal et assurer la fixation interne de l'arthrodèse.

4. Le tissu osseux periostique homogène et hétérogène est une substance relativement inerte bien tolérée qui est supérieure au métal puisqu'il peut être incorporé au squelette de l'hôte.

ZUSAMMENFASSUNG

1. Bearbeiteter homogener und heterogener kortikaler Knochen wurd in der Form eines H Blocks zur inneren Fixation und Spreizung der hinteren Wirbelbogen zwecks Arthrodesis der lumbosakralen Wirbelsäule mit Erfolg angewendet.

Der H Block war eine Hinzufugung zu einer interfacetaren inter laminaren interspinosen Verschmelzungsoperation mit autogenem Knochen vom os ileum

3 Das doppeltgeschichtete Implantat aus autogenem iliakalem und bearbeitetem kortikalem Knochen kann gleichzeitig die Zwischenwirbel scheibe und den Wirbelkanal erweitern und auch eine innere Fixation fur eine Arthrodesis liefern

4 Bearbeiteter kortikaler homogener oder heterogener Knochen ist ein gut vertragliches verhaltnismassig neutrales Material das insofern Metallen uberlegen ist als es in das Skelett des Empfangers einverleibt werden kann

ACKNOWLEDGMENT

J A Dingwall MD Squibb Institute for Medical Research New Brunswick NJ USA kindly donated the processed bovine heterogenous bone for the patients in this study

REFERENCES

1 *Abbott L C Schotstaedt E R Saunders J B & Bost F C* The Evaluation of Cortical and Cancellous Bone as a Grafting Material J Bone and Joint Surg 29 381 1947

2 *Andersson K J Clauson D K & LeCocq J F* Personal communication

3 *Barr J S* Low Back Pain and Sciatica J Bone and Joint Surg 33 A 1049 1951

4 *Bass H C & I* A Possible Substitute for Preserved Homograft Surg Forum 12 445 1961

5 *Billingham R E Brent L & Medawar P B* The Antigenic Stimulus in Transplantation Immunity Nature *178* 154 1956

6 *Bosworth D M* Clothespin or Inclusion Graft for Spondylolisthesis and Laminal Defects of the Lumbar Spine Surg Gynec and Obst 75 593 1942

7 *Bosworth D M* Techniques of Spinal Fusion Pseudarthrosis and Method of Repair Instructional Course Lecture Am Acad Orthopedic Surg 5 299 1948 J Edwards and Co Ann Arbor Mich USA

8 *Brack L W & Basom W C* The Flexion Treatment for Low Back Pain Indications outline of Conservative Management and a New Spinal Fusion Procedure J Bone and Joint Surg 25 58 1943

9 *Burwell R G & Gowland G* Studies in the Transplantation of Bone J Bone and Joint Surg *44B* 131 1962

10 *Friberg S* Studies on Spondylolisthesis Acta Chir Scandinav Suppl 55 82 1939

11 *Friberg S* Low Back and Sciatic Pain Caused by Intervertebral Disc Herniation Acta Chir Scandinav Suppl 64 8 1941

12 *Friberg S* Anatomical Studies on Lumbar Disc Degeneration Acta Orthop Scandinav *17* 224 1948

13 *Friberg S & Hirsch C* On the Late Results of Operative Treatment for Intervertebral Disc Prolapses in the Lumbar Region Acta Chir Scandinav 93 161 1946
14 *Friberg S & Hirsch C* Anatomical and Clinical Studies on Lumbar Disc Degeneration Acta Orthop Scandinav *19* 222 1949
15 *Gibson A* A Modified Technique For Spinal Fusion Surg Gynec and Obstet. *53* 365 1931
16 *Knutson B & Wiberg G* On Surgically Treated Herniated Intervertebral Disks Acta Orthop Scandinav *28* 108 1958
17 *Leikkonen O* Low Back Pain and Sciatica Acta Orthop Scandinav Suppl *15* p 37 1959
18 *Medewar P B* Iso antigens In Biological Problems of Grafting Edited by F Albert and P B Medewar Blackwell Scientific Publications Oxford 1952
19 *Orell S* Studien uber Knochenimplantationen und Knochenneubildung Implantation von Os Purem sowie Transplantation von Os Novum" Acta Chir Scandinav *74* Suppl 31 173 1933
20 *Orell S* Principles and Experiences at the Implantation of Os Purem Os Novem and Bone Granulate Acta Orthop Belgica *8* 162 1932
21 *Unander Scharin L* On Low Back Pain with Special Reference to the Value of Operative Treatment with Fusion Acta Orthop Scandinav 5 149 1950
22 *Urist M R* Physiologic Basis of Bone Graft Surgery Clin Orthop *1* 207 1953
23 *Urist M R* Bone Transplants Implants Derivatives and Substitutes—A Survey of Research of the Past Decade Instructional Course Lectures Am. Acad Orthop Surg *17* 184 1960
24 *Urist M R MacDonald N S & Jowsey J* The Function of the Donor Tissue in Experimental Operations with Radioactive Bone Grafts *147* 129 1958
25 *Urist M R & McLean F C* Osteogenetic Potency and New Bone Formation by Induction in Transplants to the Anterior Chamber of the Eye J Bone and Joint Surg 34 443 1952
26 *Urist M R Maet R W Jr & Bechtol C O* Senile Osteoporosis as a Disorder Influencing Treatment and End Results of Fractures of the Hip with A Preliminary Report on the Use of Collapatite Am Surg 25 893 1959
27 *Urist M R & Moon N F* Fractures of the Hip in Patients with Severe Osteoporosis J Trauma *1* 373 1961
28 *Weinberg H Makin M Nelken D & Gurevitch J* A and B Antigens in Human Bone Tissue J Bone and Joint Surg *41 B* 151 1959
29 *Wiberg G* Back Pain in Relation to Nerve Supply of the Intervertebral Disc Acta Orthop Scandinav *19* 211 1949
30 *Wiberg C & Stahl F* Low Back Pain and Sciatica J Bone and Joint Surg 33 B 471 1951
31 *Wiberg G* Myelography in the Diagnosis of Disc Protrusion J Bone and *Joint Surg 43 B 857 1961*
32 *Wiberg C* Electromyography as an Aid to the Diagnosis of Lumbar Nerve Compression J Bone and Joint Surg *43 B* 857 1961

FROM THE ORTHOPAEDIC CLINIC HÄRNÖSAND
HEAD NILS LINDSTRÖM M D

MUSCLE TRANSPOSITION IN SERRATUS ANTERIOR PARALYSIS

By

NILS LINDSTRÖM and LARS DANIELSSON

Winged scapula or scapula alata follows paralysis of the Serratus anterior muscle and is characterized clinically by a prominence of the vertebral border and inferior angle of the scapula and by an inability to lift the arm above shoulder level The muscle is innervated by the long thoracic nerve Paralysis may be due to trauma neuritis or progressive muscular atrophy

Therapeutically an abduction splint or figure of eight bandage and physiotherapy are first employed In those cases where the paralysis continues two types of surgical procedures have been used scapular fixation and muscle transposition The method evolved by Hass belongs to the latter group in which the Teres major muscle is transposed to restore the function of the paretic Serratus anterior muscle

The Serratus anterior muscle takes its origin from ribs 1–8 beneath the Pectoralis minor muscle and is inserted into the inferior angle and vertebral border of the scapula (see fig 1) The Teres major which is innervated by the subscapular nerve takes its origin from the inferior angle of the scapula and is inserted on the crest of the lesser tuberosity of the humerus somewhat dorsally and distally to the insertion of the Latissimus dorsi

The operation is carried out as follows see figs 2 and 3

An incision is made in the axilla parallel with the posterior fold After the neurovascular structures have been carefully retracted the Teres major is freed subperiosteally from its humeral insertion Through a second incision on the upper lateral thorax the 5th and 6th ribs are exposed at the level of origin of the Serratus anterior By means of a suture the humeral end of the Teres major is now drawn across the

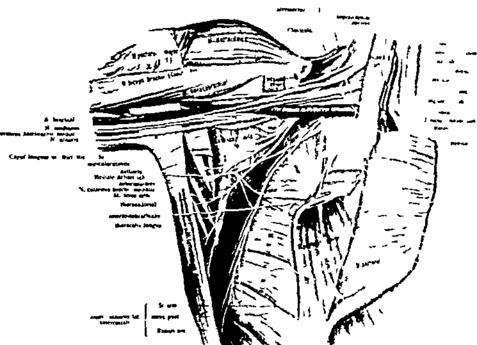


Fig 1
Anatomy of the shoulder region

axilla deep to the Latissimus dorsi and after division into two parts inserted subperiosteally into the 5th and 6th ribs

Since identification and separation of the Teres major from the Latissimus dorsi can be difficult the surgeon is advised first to perform the tranposition upon section material

At the Orthopaedic Clinic in Harnosand this operation has been carried out upon 5 patients 3 women and 2 men The age at operation varied from 21 to 49 years The etiology of the paralysis was direct trauma in two cases heavy lifting in one case spinal neurogenous muscle atrophy in one case and in one case it was unknown The patient with muscle atrophy had bilateral Serratus paralysis The operation was performed on the right side in 4 cases and on the left side in one case

The interval between the onset of the paralysis and the operation was from 6 months to 8 years with an average of 3 years During this period conservative treatment such as physiotherapy local anaesthesia local cortisone radiological therapy etc was administered without apparent effect upon active shoulder mobility

Re examination was carried out 1/2–13 years after the operation

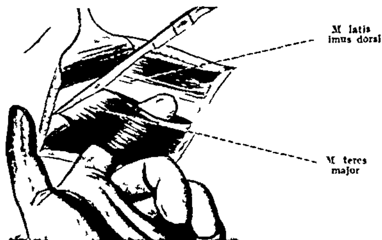


Fig 2
Release of the insertion of the Teres major from the humerus

In all cases the operation was performed under general anaesthesia Post operatively the arm was maintained in abduction for 6 weeks then physiotherapy was begun

At the follow up three of the patients stated that they were enthusiastic about the results of the operation one was satisfied and one was dissatisfied

Four of the patients were able to return to their previous work and declared that they had only insignificant trouble from the shoulder such as a feeling of tiredness after working with the arm above the horizontal level or smarting pain from the new muscle insertion on the ribs

On objective examination it was found that the result of operation was successful in four cases and unsuccessful in one case (the atrophy case)

Three patients had a normal range of active shoulder motion one patient had 20 restriction of elevation but otherwise free mobility One patient s condition was unchanged from the pre operative status i e the arm could only be lifted forward upward and outward upward to 10 below horizontal level

The lifting ability of the horizontal arm was measured with an ergometer and the result compared with the healthy arm In the four successful cases this examination produced an average value of 7 10 when measuring forward upward and 8 10 when measuring outward upward

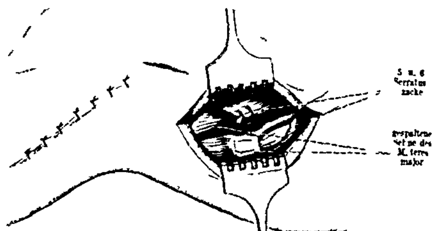


Fig 3
Subperiosteal attachment of the Teres major to the 5th and 6th ribs

The unsuccessful case had bilateral pareses so that the value from the healthy arm could not be obtained

Normal scapular rotation was present in all cases except 1

The tranposed muscle could be clearly palpated in three cases

In the unsuccessful case scapula alata was still present at rest while in the other four cases only insignificant winged scapula was seen and then only when the elevated arm bore weight

No restriction of mobility could be observed in the elbow wrist or fingers nor did neurological disturbances arise after operation

The true strength of the hand on the operative side measured with a dynamometer was somewhat reduced and on average was 9 10 of that on the healthy side

The cause of the failure in the case with muscle atrophy may partly have been atrophy in the tranposed muscle partly its coming loose from the site of implantation

Before operative measures are taken conservative treatment should be tried for at least ½–1 year when the possibility of reinnervation exists EMG examination may be a guide

CONCLUSION

Transposition of the Teres major muscle according to Hass gives very good results in suitable cases of paralysis of the Serratus anterior muscle and the operation is relatively simple to perform

SUMMARY

The series comprises five cases with paralysis of the Serratus anterior muscle treated by tranposition of the Teres major according to Hass.

The etiology in three cases was trauma, in one case spinal neurogenous muscle atrophy and in one case it was unknown.

After operation four patients regained normal or almost normal shoulder function while one patient, the atrophy case, remained unchanged.

RESUMÉ

5 cas de paralysie du muscle serratus lateralis opérés par transposition du muscle teres major par la methode Hass.

L'etiologie de la parese etait un trauma dans trois cas, une atrophie musculaire spinale ou neurogene dans un cas, inconnue dans le dernier cas. Apres l'operation les quatre malades avaient retrouve une fonction normale ou presque normale de l'epaule, alors que l'etat du malade était reste inchange.

ZUSAMMENFASSUNG

Das Krankengut umfasst funf Falle von Lahmung des M. serratus lateralis die mittels Transposition des M. teres major nach Hass operiert wurden. Die Äthiologie der Lahmung war in drei Fallen ein Trauma, in einem Falle spinale oder neurogene Muskelatrophie und in einem Falle unbekannt.

Nach der Operation haben vier Patienten normale oder beinahe normale Schulterfunktion wiedererhalten, während der Zustand eines Patienten unverandert ist.

REFERENCES

Hass, J.: Konservative und operative Orthopädie, p. 191.

Hass, J.: Muskelplastik bei Serratuslahmung. *Zeitschrift fur orthopadische Chirurgie* 55, 617, 1931.

Hass, J.: Operationen bei Schulterlahmungen. Wiener klinische Wochenschrift 94 f, 1936.

Rauber-Kopsch: Lehrbuch und Atlas der Anatomie des Menschen, 1943.

Williger, Ludwig: Die perifere Innervation, p. 94, p. 147.

Campbell: Operative orthopedic, p. 984, p. 1790, 1956.

Nordisk laerebog i intern medicin, p. 20, p. 364, 19 8.

OSTEOCLASIS OF THE UPPER EXTREMITY IN CHILDREN

By

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In 1940 I published a paper entitled Osteoclasis for Supination Deformities in Children (1) and reported nine cases Since that time at the Milwaukee Children s Hospital osteoclasis has supplanted open operation in the correction of resistant bony pronation and supination deformities in children Although the technic has proved completely satisfactory in our hands it is little known in other communities

In the same year I read a paper before the Chicago Orthopaedic Society (2) suggesting the revival of the suprapectoral rotation osteotomy of the proximal end of the humerus of Vulpius (3) Spitzy (4) and others in the treatment of shoulder deformities with limited external rotation following obstetrical trauma In these cases with brachial palsy and or epiphyseal injury in addition to the rotary deformity there was usually limited active elevation although passive motion might be free almost to the pivotal position Active forward elevation was not increased by muscle release operations but was augmented almost degree for degree by angulation apex posteriorly of 40 or more at the site of the rotation osteotomy I have seen no mention elsewhere of this most important angulation feature (Figure 1)

Since the appearance of the abstract (2) this method has been used frequently in correcting deformities at both ends of the humerus involving rotation and angulation In recent years in children instead of an osteotomy we have performed a drilling osteoclasis which avoids the scar that is so objectionable in females

Through a puncture wound multiple 3 mm holes are drilled through the cortex of the bone at the desired level About three holes can be made in the deep side of the cortex through each of three holes on the near side of it The bone is then broken manually over a sharp wedge This is easy at the lower end of the humerus (Fig 6) but may be difficult at the proximal end due to the poor grip that one obtains on

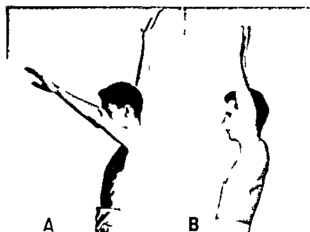


Fig 1

Case 1 T G age 15 years (A) February 20 1961 As the result of an obstetrical shoulder injury the left arm was short with active forward elevation of onl 110 Backward elevation was increased 10 Rotation outward wa 30 as compared t 60 on the right Other houlder motions were normal Po er was good through the limited range (B) April 7 1962 F urteen months after a r tati n angulati n oste t my the range of f rward elevati n is increa ed t 180 Function is ex llent The iatrogenic angular deformity i not disfiguring



Fig 2

Case 1 An anteroposterior x ray Februar 20 1961 shows a very h rt left humerus with characteristic deformity The proximal humeral epiphysis was eparated at birth with 120 rotary displacement of the epiph seal fragment so that the articular surf e came to lie caudad The clear zone of the articular cartilage is een extending up t the point of b n union n the lateral si le



Fig 3

Case 1 An x ray of the left humerus on August 17 1961 with external rotation to show the angular correction of 50 by osteotomy He was in a plaster spika (Fig. 4 for eight weeks. Healing was rapid. Improved function in rotation and forward elevation was dramatic. See figure 1B

the proximal fragment It is important at the shoulder to make an adequate number of drill holes to weaken the bone

It has not been necessary to drill the radius for a forearm osteoclasis but it might be a desirable preliminary in an adolescent with very strong bone The leverage is so good at mid forearm that osteoclasis is easy when the bones are atrophic In case seven of the original publication (1) drilling could have been used to obviate the need for a Thomas wrench as a supplement to manual force

The two methods are now reviewed together because they have a common background in that closed fractures of the shafts of the long bones of the upper extremities heal satisfactorily in children even with gross displacement With non-operative treatment a non union has not occurred in my experience *Open reduction* of fractures of the distal forearm is followed by non union in a significant number of cases even in young children We have encountered delayed union with open osteotomy of forearm bones whereas healing has been prompt in all closed osteoclases of the forearm and humerus

After twenty-two years of further experience with these methods I have no retractions to make I urge that in children all such procedures be performed closed with drilling if necessary The only detail of technic that requires discussion is the position of immobilization after osteoclasis

In treating the characteristic internal rotation deformity of the arm with failure of elevation the distal fragment must be rotated to a

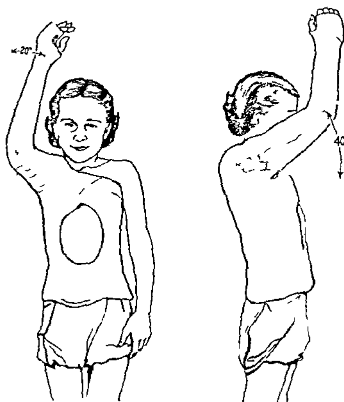


Fig 4

The pr per position of the arm in a post operative plaster spika maintains correction of the internal rotation forward elevation def rmity foll wing a drilling osteocla i of the pr ximal third of the humerus With the elbow elevated to the level of the chin neutral rotati n is not at zero but at 90 or more of internal rotation In creased f rw ard elevation is obtained by angulating the fragments

functionally neutral position and angulated upward until the elbow is as high as the chin in a young child One can angulate apex poste rior 30 without obvious deformity The fragments may be boldly dis placed with complete disregard for anatomy Every degree of angu lation is an added degree of forward elevation

In the forward elevated position one must rotate the distal fragment externally only to the salute position of O -20 (Fig 4) The proximal fragment will revert toward its previous position of internal rotation If more than O 20 of external rot ition is obtained the arm will likely be grotesquely externally rotated when it is brought down to the side

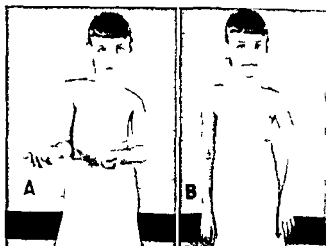


Fig 5

Case 2 K B At age six this girl had the residuals of an obstetrical trauma to the left upper extremity It was completely flail at birth She was left with no external rotation at the left shoulder (A) while other shoulder motions were normal Extension of the left elbow was reduced 25 (B) and flexion increased 10 There was an increase in the carrying angle

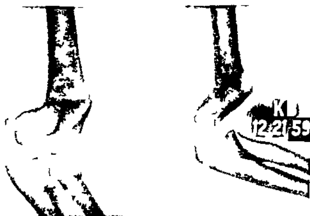


Fig 6

Case 2 K B The original x rays were not remarkable and are not reproduced. These anteroposterior and lateral views were made six weeks after a drilling o[illegible] on November 13 1959 The humerus was broken through completely above the condyles and the distal fragment was rotated outward 20 extended an additional 25 and adducted to correct the excessive valgus In this position with forward elevation at the shoulder of only 45 a plaster spika was applied for three weeks and a collar and cuff for two weeks

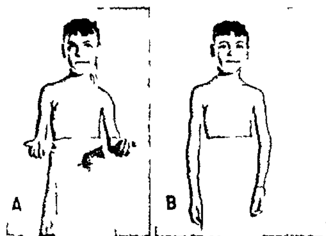


Fig 7

Case 2 Three months after the operation the rotation deformity was well corrected (A) The carrying angle was normal and extension at the elbow increased (B) Fifteen degrees of limitation of flexion was not objectionable Two years later there was no obvious deformity nor disability although limitation of motion persisted

It was necessary in one child to operate a second time to restore some internal rotation

Maximal forward elevation is desirable but one must not exceed prudent limits In one boy age 10 there was a transient radial nerve palsy from excessive distraction The fragments were completely displaced and held sharply angulated in a cast with fixed skeletal traction for five weeks (5) The shoulder that had only 45 of active forward elevation prior to operation could be elevated to 100 after the osteotomy healed

Osteoclasis of the forearm should be done with the bones in supination and the dorsum of the forearm in contact with the wedge Angulation as much as 90 should be produced and vigorously reversed in order to break the bones through completely Extreme pronation and supination deformities in young children have a strong tendency to recur A repetition of the procedure has been necessary in several cases The cast is applied with the forearm completely overcorrected If there is apprehension about the circulation there may be less than full correction in the first cast A week or two later the forearm is manipulated again under anesthesia and a cast applied with further rotation The tendency is toward under correction

The forearm is immobilized so that it looks straight The position

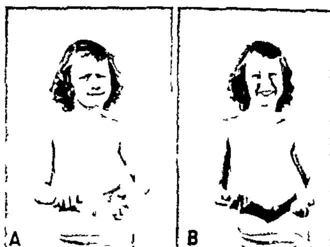


Fig 8

Case 3 S L At age nine this girl could pronate the left forearm to only 0-80 as a result of obstetrical trauma (A) Supination was normal (B) With non-operative treatment the function of the left shoulder had improved greatly There was a right right myogenic wry neck which was corrected

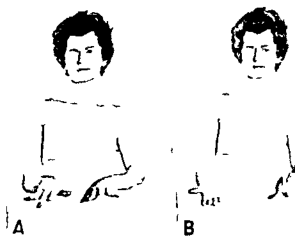


Fig 9

Case 3 Ten years after the osteoclasis the patient could still pronate to 60 on the left Supination was only 30 (B) but this was of less significance Function of the left shoulder was satisfactory A rotation angulation osteotomy of the proximal third of the humerus had not been necessary

of the bone ends is of no importance Complete displacement of the bones is usually necessary to maintain the desired position

No significant complication has been encountered The X ray will frighten the uninitiated but healing is prompt and molding soon takes care of the irregularities in children with a skeletal age under 11 in girls or 13 in boys

The range of pronation and supination is often *increased* rather than diminished after healing is complete (Fig 9)

In this age of more and more elaborate open operations it is a pleasure to recommend an old and tried orthopaedic method that is relatively simple with no likelihood of complication and one that may be applicable in a variety of situations Particularly gratifying was case two (Figs 5–7) in which the osteoclasis was done at the lower end of the humerus It accomplished not only correction of a vicious rotation deformity but changed the arc of motion at the elbow to a more useful and cosmetically desirable one After osteoclasis the girl could use her elbow with good function and without obvious deformity

I am glad to review these two procedures and recommend them again in a memorial to two great orthopaedic surgeons whose sophistication and wide experience have not alienated them from the simple procedures that are so satisfactory and safe in the correction of deformities of childhood

SUMMARY

1 Osteoclasis is preferable to open operation in the correction of fixed rotation deformities of the forearm in children

2 Drilling osteoclasis or osteotomy of the upper third of the humerus is used not only to correct internal rotation deformity but also to increase active forward elevation

3 The tendency is to overcorrect rotation of the humerus and undercorrect that of the forearm

4 In old obstetrical shoulder injuries an increase of 40 or more of active forward flexion can be obtained by angulating the fragments apex posterior

5 At the lower end of the humerus persistent angulation into flexion and valgus or varus of the elbow may corrected simultaneously with a rotation deformity

RESUME

1 Il faut preferer l osteoclasie a l operation ouverte pour la correction de deformites fixes de rotation de l avant bras chez les enfants

2 Une osteoclasie ou osteotomie par forage dans le tiers supérieur de l humerus est utilisee non seulement pour corriger la deformite de rotation interne mais aussi pour augmenter l elevation active en avant

3 La tendance doit etre de surcorriger la rotation de l humerus et de sous corriger celle de l avant bras

4 Dans les cas de vieille lesion obstetricale on peut obtenir une augmentation de 40 ou plus de la flexion active en avant par le placement angulaire du fragment de l apex posterior

5 A l extremite inferieure de l humerus une angulation persistante en flexion en valgus ou en varus du coude doit etre corrigee simultanement avec une deformite de rotation

ZUSAMMENFASSUNG

1 Osteoklase ist der offenen Operation zur Korrektur von fixierten Rotationsdeformiteten des Armes von Kindern vorzuziehen

2 Die Bohrosteoklase oder Osteotomie des oberen Drittels des Humerus wird verwendet nicht nur um die Innenrotationsdeformitet zu korrigieren sondern auch um die Vorwärtshebung zu vermehren

3 Die Tendenzbesteht die Rotation des Humerus uberkorrigieren und die des Unterarms unterzukorrigieren

4 In alten Geburtsverletzungen der Schulter kann eine Vermehrun von 40 und daruber hinaus erhalten werden wenn man den Fragment hohepunkt nach rückwäts abwinkelt

5 Am unteren Ende des Humerus kann bestehende Winkelung in Beuge Valgus oder Varusstellung im Ellbogen gleichzeitig mit der Rotationsdeformitet korrigiert werden

REFERENCES

1 *Blount W P* Osteoclasis for Supination Deformities in Children J Bone and Joint Surg 22 300 314 April 1940

2 *Blount W P* Obstetrical Shoulder Lesions Proceedings of the Institute of Medicine of Chicago 13 April 15 1940

3 *Vulpius Oskar & Stoffel A l f* Orthopadische Operationslehre 3 4 Stuttgart Ferdinand Enke 1924

4 *Spitzy Hans & Lange Fritz* Orthopadie im Kindesalter 429 Leipzig F C W Vogel 1930

5 *Blount Walter P* Fractures in Children 17 Baltimore The William & Wilkins Co 1955

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UNUNITED FRACTURES OF THE FORE ARM

By

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Experimental animal research has shown that the osteogenic layers of the periosteum are of decisive importance in the appearance of bridging callus in fracture healing With quantitative microradiography is is possible to follow the accumulation of bone salts in the callus areas and it was thus found that periosteal callus mineralises the most quickly and that it most rapidly reaches a degree of mineralisation which corresponds to that in normal bone (*Nilsonne* 1959)

The factors which interrupt this normal mineralisation in pseudarthrosis formation are so far obscure Uncertainty also prevails concerning the conditions under which a transplant placed in a pseudarthrosis heals mineralises and changes to normal bone It is also difficult as a rule to obtain sufficient material from clinical operations to study the distribution of mineral salts in a pseudarthrosis area before and after bone healing has occurred The method initiated by *Nicoll* (1956) providing for radical resection of the pseudarthrosis filling of the defect with an iliac crest block and internal fixation gives increased opportunity for the research indicated above After consolidation the operation area can be inspected and test excisions can be performed while the osteosynthesis material is also extracted

The present study comprises both clinical experience of 9 pseudarthroses operated on according to *Nicoll* (1956) and also micro radiographic research into the resected pseudarthroses (10) and into six transplants 4 after complete consolidation

MATERIAL

7 pati nt are c ncerne l perate l n during the p ri l 13 9 1961 thr (a c 3 6 and 7) ha l p eudarthr s of the ulna nly n l f ur (ca c 1 ? 4) had p eu l arthr n l th ulna an l radiu Nine of the e p udarthr e un lerwent radical

TABLE I

Summary of Operative Cases

Case Sex Age	Trauma	Fracture Ulna	Fracture Radius	Initial Treatment	Status Period before Reconstruction	Reconstruction	
1 ♂ 20	Gunshot 28 II 57	Compound	Compound	Wound Toilet + Open Reduction + Internal Fixation Subsequent Operations Due to Infection	13 VII 59	23 XI 59 Op	
2 ♂ 20	Industrial Accident (Direct Blow) 22 IV 59	Simple	Simple	Open Reduction + Cerclage	3 XII 59	8 XII 59 Op	
3 ♂ 49	Crushing Injury 3 VI 59	Compound	Simple	Wound Suture + Plaster	11 IV 60	11 IV 60 Op	3 XI 6[illegible] Rep
4 ♂ 23	Traffic Accident 2 VIII 59	Simple	Simple Disloc Capit Radii	1 Open Reduction + Cerclage 2 Rep with Rush Pin 3 Resection Capit Radii	4 X 60	5 X 60 Op	19 IV 61 Rep
5 ♀ 38	Traffic Accident 31 III 60	Simple	Simple	Open Reduction + Intra medullary Nail	11 X 60	13 X 60 Op	
6 ♂ 43	Traffic Accident 8 XI 59	Simple	Simple	Open Reduction + Rush Pin	9 II 61	1 III 61 Op	
7 ♀ 30	Traffic Accident 30 VII 59	Simple	Simple	Open Reduction + cerclage of ulna rep + bonegraft intramedullary nailing of radius	28 VII 61	31 VII 61 Op	

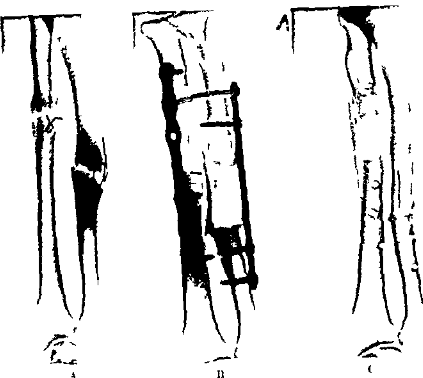


Fig. 1. A. Nonunion of the forearm 8 months after injury in a man twenty years old (case 2). —*B.* Radical resection and internal fixation has been performed. The defect measuring 3.5 and 2.5 cm resp. of ulna and radius has been filled by cancellous bone blocks from iliac crest. Opposite the plate on ulna an additional graft has been placed. —*C.* Metallic fixation has been removed 10 months after resection and bone grafting.

resection fixation with Lane's plate and also filling of the defect with autogenous cancellous bone transplant in a block. One radial pseudarthrosis was left with plaster fixation only while the simultaneous ulnar pseudarthrosis was operated on (case 4). One radial pseudarthrosis was resected radically and the resection surfaces were adjusted to good contact without transplant and fixed with a plate (case 5). The primary fracture treatment, the initial point of reconstruction and the type of reconstruction are shown in Table 1.

The preparations obtained on resection of the pseudarthroses were imbedded in methylmetacrylate and thin sections were prepared. The sections were cut through the pseudarthrosis end at varying distances from the pseudarthrosis gap and were afterwards subjected to microradiographic examination according to the technique used by *Nilsonne* (1959). Preparations from fully healed transplants 10–15 months after operation (case 2 and 5) and also from partially healed transplants obtained on reoperation 6 and 11 months afterwards were examined in an identical manner

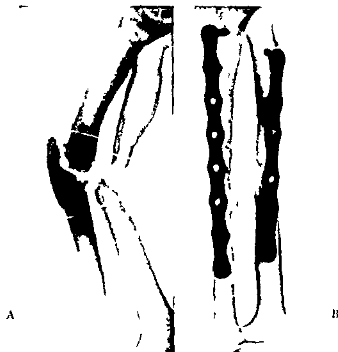


Fig 2

A Non union of the forearm 2½ years after compound fractures in a man twenty years old (case 1) Before referral the patient had an infected draining untable non union classified as non operable *B* After resection internal fixation and filling the gaps by autogenous cancellous bone block healing occurred in 6 months Roentgenogram made 1¼ year after bone grafting

OPERATIVE TECHNIQUE

The forearm pseudarthroses were exposed under general narcosis in six cases and plexus anesthesia in one case Resection of the pseudarthroses including the sclerotic fracture ends was performed with a Gigli saw to such an extent that the medullary cavity was plainly open in the resection surface This means that 1 2 cms were resected from every pseudarthrosis end Lane plates with two or three screws in each fragment restored stability and shape afterward The bone defects between the resection surfaces (tables I and II) were filled with an autogenous cancellous bone block taken from the iliac crest (fig 1) It was not necessary therefore to the resection to any live any shortening even if it did concern pseudarthrosis defects (fig 2)

In one case with a large angle between the fragments a certain shortening was however desirable bearing in mind the soft tissue contractures (case 5) After the resections a good end to end contact was first established in this case between the radial fragments which were fixed by plate and screws Between the ulnar fragments a defect of 1 8 cms remained The fragments were fixed with Lane's plate The defect was filled with cancellous bone from the iliac crest (fig 3)

TABLE II

Size of the bone defects

Case	Ulna	Radius
1	3.5 cms	2 cms
2	3.5 cms	2.5 cms
3	2.5 cms	–
4	2 cms	not explored
5	1.8 cms	contact between resection surfaces
6	1.8 cms	
7	2 cms	

COMPLICATION

In case 1 a minor necrosis arose on the operation scar above the radius with recurrence of previously troublesome eczema of the forearm but the course of healing was not affected. Otherwise all operation wounds of the forearm healed without trouble. In case 3 healing of the wound above the iliac crest (site of graft) was delayed 2 weeks owing to staphylococcic infected haematoma.

TABLE III

Healing of cancellous bone transplant

Case	Post-operative plaster fixation mth	Cancellous bone block healing: Ulna prox.	Ulna dist.	Radius prox.	Radius dist.
1	4	+	+	+	+
	3.5	+	+	+	–
3	4	—	+	–	
4	5.5	—	+	union	
5	5	+	+	end to end	
6	3	+	+	— — –	
7	7	+	+	– – –	

healed after second intervention + improved fixation

reoperation + improved fixation

CLINICAL RESULT

Out of 9 pseudarthroses treated according to Nicoll 7 healed within 3–7 months, 2 after re-operation and a further 6 months plaster fixation. A radial pseudarthrosis treated with radical resection, end to end contact and internal fixation without bone transplant healed in 5 months (case 5). A radius pseudarthrosis not explored healed in 4

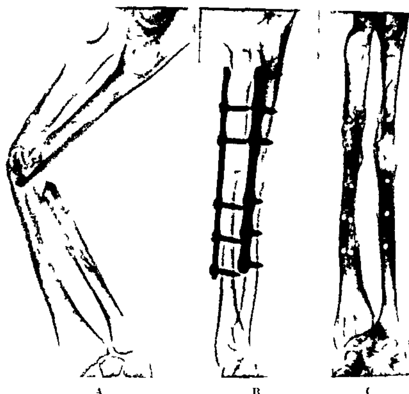


Fig. 3

A Non-union of the forearm with dislocation 6 ½ months after simple fractures in a woman thirty eight years old. *B* The system was shortened by resection and end to end adaption of the radius. The defect of the ulna after resection was filled by cancellous bone block. Healing occurred in 5 months. Roentgenogram made 7 months after the reconstructive surgery. *C* Plate and screws removed 15 months after reconstructive surgery.

months with simultaneous immobilisation of the ulnar pseudarthrosis (case 4). See table III.

The clinical study comprises 11 diaphyseal forearm pseudarthroses in 7 patients. All healed with a good anatomical result, i.e. with full stability without deformity of the forearm. Varying degrees of muscle atrophy could be observed and also a certain reduction of the strength of the hand grip (Table IV). All are able to work.

MICRORADIOGRAPHY OF RESECTED PSEUDARTHROSES

The microradiographic appearance of the pseudarthrosis ends some mms from the actual pseudarthrosis gap showed a large number of

TABLE IV

Follow up 19[illegible]

Case	Short.	Atrophy	Elbow	Pronation	Supination	Hand mobility
1	The same as before last op	++	180 –40	30	–30	Dorsalfl 40 Volarfl 30
2	—	+	180 –40	30	10	Dorsalfl 45 Volarfl 15
3	—	+	170 60	45	45	Dorsalfl Volarfl
4	—	+	180 –45	45	0	Dorsalfl 55 Volarfl 30
5	+	++	160 –40	15	0	Dorsalfl 20 Volarfl 15
6	—	+	175 –40	10	10	Dorsalfl 20 Volarfl 10
7	—	+	170 –40			

resorption cavities (fig 4) In the bone substance there remained osteones with a mineral salt distribution which could be described as normal In other words the distribution of mineral salts was of the same type as that in quite healthy bone and of the same type as in sections taken at longer distances from the pseudarthrosis zone

In the intermediate regions between the Haversian systems an inhomogeneous distribution of bone salts occurred

The sclerosis of the pseudarthrosis ends observed on macroscopic X rays found no correspondence on a microscopic level in the form of hypermineralised regions

The build up of periosteal callus was formed by closely lying trabeculae Here the mineralisation was analogous with that found in relatively late stages of normally healing fractures

All the pseudarthroses displayed the same type of microradiographic pictures whether they were being studied in cross sections or longitudinal sections Fig 5 is an example of a microradiogram from a longitudinal section through a pseudarthrosis (case 2) The black zone in the centre corresponds to the pseudarthrosis gap where mineralisation is completely absent This gap is sorrounded by intermediately lying callus consisting of partly very fine trabeculae The mineral salt distribution in these areas changes and large local variations occur



Fig. 5

Microradiogram of a cross section of the ulna at a distance of a few millimeters from the pseudarthrosis gap (case 2).
B = bone, pc = periosteal callus.

MICRORADIOGRAPHY OF THE AUTOTRANSPLANT

Islands of necrotic bone were observed in the six preparations examined which were obtained from test excisions. On the microradiogram these necroses emerged as strongly mineralized zones (fig. 6). Haversian systems of varying degrees of mineralisation proceeding in both transverse and longitudinal directions were encountered in several places. The arrangement of the osteones and the pattern of mineralisation indicated that an active build up of the transplant was proceeding.

DISCUSSION

There is probably widespread agreement that adequate fixation over a sufficiently long period can promote healing of certain contact pseudarthroses and that the provision of osteogenetic material hastens bone healing (*Matti* 1936, *Phemister* 1947, *Urist* (& coworkers) 1954, *Kuntscher* 1959).

As to the opposite problem, the defect pseudarthroses, the difficulties



Fig 5

Microradiogram of a longitudinal section through the p eu larthrosi of ulna (case 7) P = b ne The black area in the center reprents the n n mineralized z ne of pseudarthr si

are greater From the healing point of view many consider the pseudarthrosis tissue and the sclerotic bone as of lesser value (*Magnus* 1937) Direct adaptation of the fracture ends after radical resection always means shortening which especially with defect pseudarthroses is severe On the forearm moreover there are the further difficulties of obtaining precise adjustment and fixation for both ulna and radius A large bone graft as on lay graft on both forearm bones not infrequently promotes difficulties from the standpoint of skin covering

In the method initiated by *Nicoll* (1956) which was tried out here all pseudarthrosis tissue and sclerotic bone ends are removed and form and stability can be restored smoothly without shortening The defect is filled by a well fitting block from the iliac crest consisting chiefly of cancellous bone and with only one cortical surface Here therefore ex

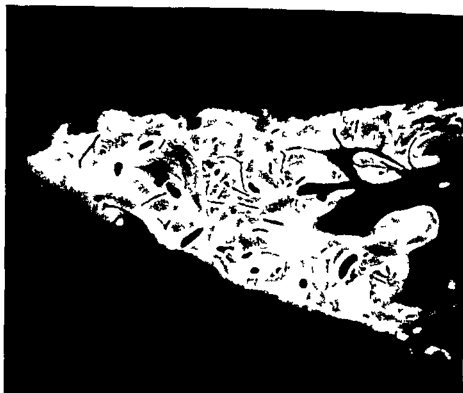


Fig 6

Microradiogram of a longitudinal section through the center part of the autogenous bone transplant of the ulna 10 months after implantation (case 7) Necrotic islands can be observed in normal internal structures of bone which seems to be under restitution

tremely good conditions are present for vascularisation of the cancellous structure of the transplant by means of the normal surrounding muscles and the resection surfaces of the bone ends with their open medullary cavities In addition the periosteum is stimulated into activity in a way which is analogous with normal fracture conditions Cases 1 2 5 6 and 7 show that fine healing may occur in this manner Clinically and radiologically consolidation was complete as a rule after 3 to 5 months On extraction of the osteosynthesis material and the simultaneous test excision from the graft area the cancellous bone transplant could not be macroscopically distinguished from the host bone Whether the incorporation of the cancellous bone block occurred by means of new bone formation beginning chiefly from the resection ends and the periosteum or from the surroundings could not be decided

In cases 3 and 4, which were operated on secondarily after 5 and 11 months respectively, owing to absent consolidation, the defective healing was localised not to the centre of the transplant but to the proximal border between transplant and host bone. Otherwise the transplants were macroscopically changed to vital bone.

At a microscopic level scattered necrotic islands could be observed in these transplants and also in fully consolidated blocks up to 15 months after the transplantation. The localisation of the necrotic areas gave no definite guide in deciding how the transplant was replaced by the newly formed bone tissue. Nor can the point be excluded that certain areas of the autogenous cancellous bone block may in fact have survived. That autogenous cancellous bone transplants in suitable environments may preserve their vitality has been shown by *Levander* (1941) amongst others. Continued research into transplants in different stages of healing employing biophysical techniques is planned, so that further light may be thrown on these problems.

That the clinical result was not equally as good primarily in all cases is probably due to technical deficiencies. The internal fixation by plate must be extremely reliable and ought to comprise at least 3 screws proximally and 3 distally. Another factor which is certainly also of fundamental importance is the insertion of the cancellous bone block—it must be pressed in and must not be too small. The transplant must in other words take up a stable position between the resection ends.

The significance of mechanical strain, especially the torsion forces of high ulnar fractures and their pseudarthroses has been pointed out by several authors, amongst others *Rehnberg* (1953), *Boyd* and others (1961), *Moberg* (1961). In order to avoid carrying on rotatory movements of the upper arm to the fracture and pseudarthrosis area proximally on the ulna, the fixation should comprise a thoraco-brachial plaster.

SUMMARY

Out of 11 forearm pseudarthroses in 7 patients, 10 underwent radical resection + internal fixation by plate. In one case where shortening was desirable end-to-end contact was established; in 9 cases the bone defects were filled with autogenous cancellous bone blocks. All healed with good anatomical and functional results, but 2 ulnar pseudarthroses only healed after re-operation. In the remaining cases consolidation occupied 3–7 months. The resected parts were examined by microradiographic technique for the distribution of mineral salts and comparative

mineralisation studies were performed after test excisions on healed transplants.

The clinical experience obtained by using this operative method and the microradiographic findings are discussed.

RÉSUMÉ

Sur 11 pseudarthroses de l'avant bras chez 7 malades il a été pratiqué chez 10 une resection radicale + fixation interne par plaque. Dans un cas, *le raccourcissement était désirable*, un contact entre les extrémités fut établi; dans 9 cas, les défectuosités de l'os ont été remplies par des blocs d'os autogène dur.

Dans tous les cas guérison avec de bons résultats anatomiques et fonctionnels, mais pour 2 pseudarthroses ulnaires seulement après réopération. Dans les autres cas la consolidation s'est opérée entre 3 et 7 mois. Les parties extirpées ont été examinées suivant la technique microradiographique pour établir la distribution des sels minéraux et des études comparative de minéralisation ont été pratiquées après excision de prélevements des transplantations guéries.

L'expérience clinique acquise par l'utilisation de cette méthode opératoire et de ces trouvailles microscopiques est discutée.

ZUSAMMENFASSUNG

Von 11 Unterarmpseudarthrosen bei 7 Patienten wurden 10 einer radikalen Resektion und internen Fixation mittels Platten unterzogen. In einem Falle, in dem eine Verkürzung wünschenswert war, wurde ein End zu End Kontakt errichtet. In 9 Fällen wurde der Knochendefekt mit autogenen Spongiosablöcken ausgefüllt.

Alle heilten mit gutem anatomischen und funktionellen Ergebnis, aber 2 Ulnapseudarthrosen heilten nur nach Reoperation. In den übrigen Fällen *nahm die Konsolidierung* 3 – 7 Monate in Anspruch.

Die resezierten Teile wurden mittels einer mikroradiographischen Technik zur Feststellung der Verteilung von Mineralsalzen untersucht und vergleichende Mineralanreicherungsstudien wurden nach Probeexcisionen von geheilten Transplantaten ausgeführt.

Die klinische Erfahrung, die anlässlich der Verwendung dieser Operationsmethode erhalten wurde, und die mikroskopischen Befunde werden besprochen.

REFERENCES

Boyd H B Lipinski S W Wiley J H Observations on non union of the shaft of the long bones with a statistical analysis of 842 patient J Bone & Joint Surg 43-A 159 1961

Kantsch r G Der Heilungsvorgang bei der Pseudarthrose Zbl Chir 84 59 1959

Lexan ler G Einige Gesichtspunkte zur operativen Pseudarthrosebehandlung Acta chir Scand 85 148 1941

Magnus G Wesen und Behandlung der Pseudarthrose Arch f klin chir *189* 191 1937

Matti H Resultate meiner Pseudarthrosenoperation Zbl f Chir *63* 1442 1936

Moberg E Metal plate without screws for fixation of haft fracture f the fore arm Acta orthop Scand *31* 229 1961

Nicoll E A The treatment of gaps in long bones by cancellous insert graft J Bone & Joint Surg *38 B* 71 1956

Nilsonne U Biophysical investigations of the mineral phase in healing fractures Acta orthop Scand Suppl 37 1959

Nils nne U The distribution of mineral salt in non union f fra ture Acta Orth p Scand *31* 81 1961

Phem ster D B Treatment of ununited fractures by on la graft without scre or tie fixation and without breaking down of the fibrous uni n J B ne & Joint Surg 29 946 1947

Urist M R Ma et R and McLean F C The pathogenesis and treatment of de layed union and non union J Bone & Joint Surg 36-A 931 1954

ON THE TREATMENT OF THE LOSS OF OPPOSITION

By

A. S. PALAZZI

Almost everything has already been said about the surgical approach to restore the opposition of the thumb. I intend only in this paper to expose the simple technique we employ.

Opposition is a complex movement in which 4 long muscles and 4 short ones are used, and consists in a combined *extension* (by the short and the long extensors), *abduction* (by short and long abductors), *flexo pronation* (by the short and long flexors and the short abductor), *opposition* (by the opponens and the short flexor) and *adduction* (by the adductor).

This complexity makes a difference between the ideal result reached when only the motor thenar branch of the median nerve is cut and those of the severe parallized hand of some poliomyelitic patients. Between these two extreme cases we can see many degrees.

Of course before performing any tenoplasty the joint must be mobile and if necessary we perform a capsulectomy of the carpometacarpal joint with or without rotatory osteotomy on the metacarpal. When the deformity is too fixed we carry out extirpation of the trapezium keeping the metatarsal bone in place with a Kirschner wire for three weeks.

The tenoplasty technique I have employed in our last 53 cases of loss of opposition has been as follows:

The pulley. I use as pulley the natural one made by the abductor digiti quinti in its insertion in the pisiform bone.

I think this pulley is a very good one because it never slips, as often happens using the tendon of the flexor carpi ulnaris; because many traumatic patients have scars in the forearm and it is too dangerous to make pulleys near them; because it works equally well whether we use muscles from the anterior side of the forearm or from the dorsum as a motor; and because the first essential principle of tenoplasty for opposition expressed by *Bunnell* is: The tendon should pass in the direction of the pisiform bone.



Fig 1



Fig 2



Fig 1



Fig 2

Fig 1 J I L. Transplant sublimis of the ring finger
Fig 2 F P Free graft and motor with flexor carpi ulnaris





Fig 3
A C Free graft and extensor carpi radialis as motor

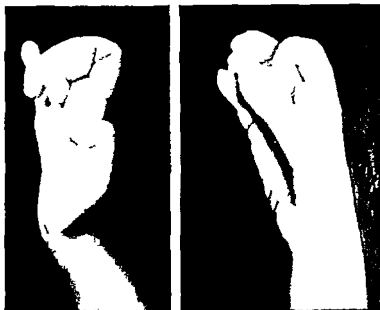
The tenoplasty We consider the best to be the transfer of the sublimis tendon of the ring finger passing by the pulley (fig 1)

When the sublimis of the ring finger is not available we use a free graft from the plantaris tendon and for motor power some carpal flexor (fig 2)

When no carpal flexor is available we cross the graft around the ulnar border of the forearm after passing via the pulley and we use as motor the extensor carpi radialis or the extensor carpi ulnaris (fig 3)

Those hands in which the described techniques cannot be performed are very severe paralytic hands Many authors as a final resort make a bone bridge between the first two metacarpals I have also performed some bone block operations But I have changed my mind In almost all the severe cases one muscle is spare very often the long flexor of the thumb and it is possible to obtain a better result by making an arthrodesis of the thumb with a Kirschner wire and transplanting the flexor pollicis longus by the usual pulley as fig 4 shows

If the flexor pollicis longus is not available we make a free graft from



before after

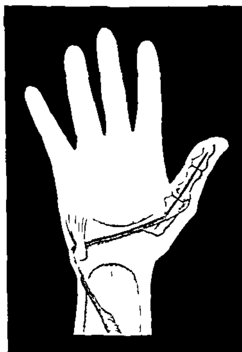


Fig 4

J M Arthrodesis with wire and *trasplant of the flexor longus of the thumb*

the plantaris muscle after the arthrodesis, and use as a motor some flexor or extensor carpi.

In 4 cases secondary tenolisis was performed.

In one case during the tenolisis the graft broke and a new transplant was done.

76 cases were operated on through this technique.

SUMMARY

The author shows the treatment he uses loss of opposition, the pulley he employs and a special technique for the very weak paralytic hands.

RESUMEN

El autor describe la tecnica que emplea en la perdida de la oposicion. La polea de reflexion que usa y una tecnica para los casos de manos graves poliomieliticas.

RESUME

L'auteur decrit le traitement qu'il applique, la poulie qu'il utilise et une technique particuliere pour les mains paralytiques tres faibles.

ZUSAMMENFASSUNG

Der Verfasser weist die Behandlung vor, die er in Fällen von schlaffer Opposition anwendet, den Rollenzug, den er verwendet und eine spezielle Technik für die besonders schwache paralytische Hand.

FRACTURES OF THE PROXIMAL AND MIDDLE PHALANGES OF THE FINGERS

By

J I P JAMES
University of Edinburgh

Fractures of the proximal and middle phalanges of the fingers present difficult and unsolved problems In the Royal Infirmary Edinburgh over the last four years we have had an opportunity of following up 196 of these and the results are presented with a discussion of some of the problems involved

It must be explained why fractures of these two bones are considered separately from those of the metacarpals and the distal phalanges Although fractures of the metacarpals present some similar problems the mutual support they provide each other makes them relatively easy to treat. Moreover skin cover is rarely a problem tendon injuries are uncommon and the tendons are not at this level an intimate relation of the bone It is instability of a finger that presents a major difficulty in contrast to the metacarpals

Injuries of the end of the fingers are problems of skin and pulp damage not of the distal phalanx

As this is a study of the fractures of these phalanges those patients who had fractures of the metacarpal or distal phalanx of the same ray are excluded from the series A number of fingers with fractures have had primary amputation because of ischaemia they also have been excluded

In considering the result of treatment in this series the fractures have been divided into groups according to the treatment necessary Although within each group there are fractures of varying types *the* most important factor other than associated soft tissue injury has been the stability or otherwise of the fracture

A fracture of either phalanx which is stable will if treated by mobilisation usually obtain full function Unstable fractures almost invariably lose some function and are divided into two groups those

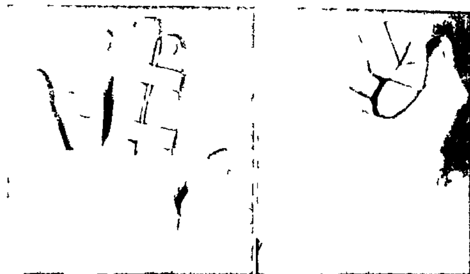


Fig 1

Carter strapping as used for some stable fractures

stable with plaster after reduction and those requiring internal fixation.

STABLE FRACTURES OF THE PROXIMAL AND MIDDLE PHALANGES

A total of 96 finger fractures were judged to be stable and treated by minimum splintage for a week or two followed by mobilisation or were mobilised from the beginning. In this series no loss of position was recorded and with increasing experience more were left unsplinted.

The normal mode of limited splintage was by means of "garter" strapping to the adjacent finger (Fig. 1).

In the 96 stable fractures of proximal and middle phalanges of the fingers there were 20 patients with some loss of function. In 16 the loss of function consisted of a failure of extension at the proximal interphalangeal joint of between 5–15° and/or loss of flexion of the finger nail to the distal palmar crease of between ¼–1". These losses are functionally not serious and the more severe cases had contributory factors: contracted skin scars, multiple fingers injured, fractures into the joint, late diagnosis and mobilisation, etc. It was rare in this group of relative failures to see a loss greater than 10° in extension and ½" of flexion. The remainder of the hand was normal.

In four patients a greater loss of function occurred: up to 30° flexion contractures at the proximal joint and 1" loss of flexion



Fig 2a *Fig 2b*

Fig 2a and b

Juxta epiphyseal fractures of the proximal phalanx of the littl finger and ring finger After reduction these are usually stable

TYPES OF STABLE FRACTURE

Criteria as to stability are obviously difficult to define and only with experience is the stability of some types appreciated Under anaesthesia stability is often easy to confirm

JUXTA EPIPHYSIAL FRACTURES OF THE BASE OF THE PROXIMAL PHALANX

In 25 fingers the proximal phalangeal base was the site of a classical juxta epiphysial or metphysial fracture with the typical triangular fragment of such fractures These fractures were only seen in children between the ages of 12 to 16 years In the fingers they occur almost exclusively in the little finger but with a few in the ring finger Fig 2a & b

If requiring reduction and most do not stability has always subsequently been maintained with garter strapping even with activity

OTHER STABLE FRACTURES

Many of the injuries seen in the Hand Clinic arise from coal mining falls of stones on to the hand produce a great variety of stable transverse or irregular fissured fractures Fig 3a & b Oblique fractures are usually unstable but the two fingers in Fig 4 remained stable despite mobilising full function was restored

Transverse fractures may be stable and experience increasingly demonstrates the advantages of early movement Fig 5 shows a fracture which remained stable and to which full function was restored in three weeks

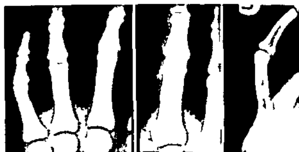


Fig 3a and b
Stable transverse and fissure fractures of the phalanges

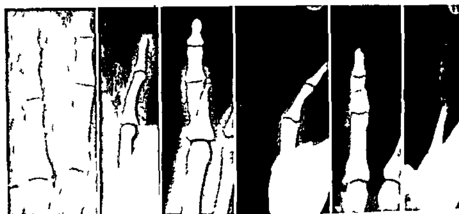


Fig 4 *Fig 5*

Fig 4 and 5
An oblique fracture is usually unstable However these were clinically stable and this was confirmed after treatment by mobilising—An impacted fracture which proved stable the patient obtained early restoration of full movement with no immobilisation

UNSTABLE FRACTURES TREATED BY REDUCTION AND PLASTER

There were 68 patients with 75 injured fingers with 17 fractures of the middle phalanx and 58 of the proximal phalanx These were judged to be too unstable to be without splintage Seven patients had two fingers broken With increasing experience the indications for plaster decrease and some of these patients would now be regarded as stable and left unsplinted

Seventeen fingers made a full recovery 4 of these were one of two fingers injured The remainder 58 in number lost some function



Fig 6

A transverse fracture of the proximal phalanx of characteristic type unstable and requiring plaster immobilisation after reduction An unusually good reduction



Fig 7

Another fracture of the proximal phalanx shaft showing pre operative and post operative positions and an X ray showing the desired position of the finger in plaster



Fig 8

Fracture of the neck of a phalanx is a difficult problem because the distal fragment rotates 90 or 180 If reducible they can usually be maintained in plaster

Loss of function arises from associated injuries as well as the fracture compounding occurred in 19 in 6 tendons were also injured and in 10 the joint surfaces were fractured Only one finger with a complicating injury was restored to full function In the whole series complicating soft tissue injuries almost inevitably precluded a return to normal A few patients with inadequate reduction regained full function

Flexion contracture at the proximal interphalangeal joint occurred in almost all the 58 nearly as common was a loss of full flexion from stiffness of the interphalangeal joints particularly the proximal The metacarpo phalangeal joints were all normal in this series Seven patients had an appreciable angulation or rotation at the fracture site Four fingers required late amputation one for stiffness one for delayed gangrene and two for sepsis following skin loss

Reduction was performed under local or general anaesthesia after reduction a dorsal plaster was used with the metacarpo phalangeal joint flexed if possible to 70 and the interphalangeal joints flexed as near to 20 at the *proximal and o –10 at the distal as was possible* Figs 6–8

Following this treatment contractures of the metacarpo phalangeal joints have not occurred but flexor contractures of the interphalangeal joints have been a continuing problem despite the decreased flexion used The hand is elevated and exercised following reduction No complicating stiffness of an uninjured finger has occurred and the metacarpo phalangeal joints have remained mobile The plaster is retained for three weeks and then removed Callus does not appear at this time in the X ray but only one phalanx has refractured

UNSTABLE FRACTURES TREATED BY OPEN REDUCTION OR INTERNAL FIXATION

Of this small group of 25 patients 9 had fractures of the middle phalanx and 16 of the proximal phalanx Only 2 fingers obtained full function

Indications for open reduction were fractures difficult to maintain after closed reduction and plaster or where treatment was begun late when mal union had commenced Increasingly *unstable fractures* were fixed primarily where experience indicated its necessity

The principal indication for internal fixation primarily is an oblique fracture of a condyle Fig 9 *Oblique fractures* were rarely stable and



Fig 9
Oblique fractures of the condyles are almost invariabl[illegible] [illegible]ause sev[illegible]re[illegible] tion of the fingers and require internal fixat[illegible] [illegible] a [illegible]mall pin



Fig 10
Cross destruction of the joint is best treated by prim[illegible] arthrodesis one te[illegible]hn[illegible]qu[illegible] is illustrated here

often difficult to hold in plaster Failure resulted in angulation of the finger or occasionally rotation with overlap on flexion

Technically the procedure is difficult particularly if done late or if the fragment is small Pin fixation proved the most satisfactory a fine hypodermic needle or wire suture was necessary when the fragment was very small the result was often poor

Ten patients had joint involvement in four primary arthrodesis was performed because of joint destruction particularly indicated if the extensor apparatus is also destroyed Fig 10 A man had a saw mill accident in which he lost dorsal skin and tendon with grossly comminuted fractures of two fingers Fig 11 Pin fixation and skin graft converted two very badly damaged fingers into useful digit with full movement at the metacarpo phalangeal joint but with no interphalangeal joint range



Fig 11

This man sustained gross skin tendon and b ne injuries and had already l t his index finger The end result was a functional finger with arthr de e l proximal in terphalangeal joints and normal movement proximally



Fig 12

Open reduction and finger pin fixation is a sati fact r meth d f r *fracture* which prove unstable in p la ter



Fig 13

An alternative method u ing tw p ins t increa e th tabilit If tw p in are u ed it is usually better n t to cr them as in the figure here This tend to cau e dis traction

A typical pin fixation is seen in Fig 12 which gave excellent although not normal function Two pins Fig 13 usually gave greater difficulty and loss of function although in this finger full function was restored

Transverse or oblique shaft fractures were treated by open reduction alone (rarely possible) by pin fixation or on four occasions by an intramedullary bone graft from the olecranon On one occasion a bone bank graft was used but this was slow to join

If the fracture is compound involves a joint or a tendon it is all but certain that there will be some loss of function The fracture that needs open reduction and pinning is unlikely to be restored to normal function The fingers showed loss of flexion and a varying degree of flexion contracture at the proximal interphalangeal joint The loss was rarely disabling but two fingers were finally amputated because of disabling stiffness and two from primary skin loss and late infection

Despite this depressing picture it is believed that internal fixation has an increasing indication The fingers may be severely damaged and it may well be impossible to save them otherwise The pins when placed are cut off subcutaneously this allows early movement Loss of function in several instances has been due to poor technique pins being deliberately passed through joints or through the extensor expansion neither has proved wise Crossed pins tended to hold the fractures apart but could not always be avoided poor apposition and fixation also caused failure Delay in undertaking open reduction was certainly a frequent error

It is believed that with our present appreciation of the indications the percutaneous pinning possible with the image intensifier and closed circuit television will materially improve results

DISCUSSION

Fractures of the phalanges have varied complications special to the fingers as well as those such as non union or infection common to all fractures

Forward angulation of a fractured shaft is occasionally persistent and may limit flexion Lateral angulation as small as 5 will cause overlapping of the flexing fingers The fingers flex towards the scaphoid and a rotational deformity will also cause overlap and difficulty

The finger joints are notoriously liable to contracture The metacarpo-phalangeal joints unless held in 60 –90 flexion during treat

ment will develop within two to three weeks a permanent extensor contracture limiting flexion. The interphalangeal joints particularly the proximal rapidly develop flexion contractures when held in flexion or extensor contractures if the finger is splinted straight the latter particularly causing a loss of function. Few fractures of the phalanges requiring plaster or internal fixation avoid minor flexion contractures of the proximal interphalangeal joint as a permanent sequel.

TENDONS

It is common for tendons to be lacerated or cut in association with fractures. The combination often presents insuperable difficulties to the return of full function associated as it is with skin wounding.

Wounding of the extensor apparatus on the dorsum of the phalanges in association with fracture presents one of the most difficult of all problems in the hand.

SUMMARY

Fracture of the Fingers

	Total No. of Fractures	*No. with full function*
Stable	96	[illegible]
Unstable and P O P	75	[illegible]
Unstable and open reduction	25	9

The result of fractures of the proximal and middle phalanges of the fingers are closely related to the degree of soft tissue wounding skin vessels tendons and joints.

The majority of phalangeal fractures are stable and active exercises with the finger splinted by its neighbour gives in a high percentage complete restoration of function.

When unstable reduction and immobilisation in the flexed position in plaster gives very useful fingers but few are entirely normal. In most there is a small loss of flexion and extension is almost invariably limited at the proximal interphalangeal joint although often only by 5 to 10. With failure to maintain reduction in plaster or in oblique condylar fractures internal fixation with a pin cut off subcutaneously or an intramedullary graft gives adequate results despite a number of technical failures.

Delay in definitive treatment by any of the three methods was a frequent cause of serious failure.

In this paper results have been assessed in terms of limitation of joint movement and residual deformity. It was most uncommon for the patient to have a noticeable functional disability despite an imperfect result as judged by these anatomical standards.

RESUME

Fractures des doigts

	Nombre total de fractures	*Nombre d'ir[illegible] fonction[illegible]*
Stables	96	[illegible]
Instables et P O P	7	1[illegible]
Instables et reduction ouverte	[illegible]	[illegible]

Les resultats obtenus dans les cas de fractures des metacarpiens et des phalanges des doigts sont etroitement lies au degre de lesion des chairs de l'epiderme, des vaisseaux, des tendons et des articulations.

La majorite des fractures phalangiennes sont stables et des exercices actifs avec le doigt appuye par son voisin restituent completement la fonction dans un nombre eleve de cas.

Lorsque la fracture est instable, la reduction et l'immobilisation dans le platre en position de flexion donne des doigts tres utiles. Toutefois peu d'entre eux redeviennent entierement normaux. Pour la plupart il y a une perte de flexion et l'extension est presque invariablement limitée à l'articulation interphalangienne proximale et elle n'est que de 5 a 10. Si l'on n'a pas opere la reduction dans le platre ou lorsqu'il y a fracture condylaire oblique, la fixation interne au moyen d'une cheville sous-cutanee ou d'une greffe intramedullaire donne de bons resultats malgre un certain nombre de non reussites techniques.

La cause frequente d'un grave echec est l'instauration trop tardive du traitement par l'une de ces trois methodes.

Dans cette etude, les resultats ont ete repartis en fonction de la réduction de la mobilite de l'articulation et de la deformite qui subsiste. Il est assez rare que le malade souffre d'incapacite fonctionelle notable même si le resultat est considere imparfait en se basant sur ces normes anatomiques.

ZUSAMMENFASSUNG

Fingerbrüche

	Gesamtzahl der Brüche	*Anzahl mit voller Funktion*
Stabile	90	[illegible]
Unstabile und *P. O. P.*	75	17
Unstabile und offene reposition	25	2

Die ergebnisse der Behandlung von Brüchen der *proximalen und* Mittelphalangen der Finger sind eng mit dem Grade der Verletzung der Weichteile, der Haut, der Gefässe, Sehnen und Gelenke.

Die Mehrzahl der Phalanxbrüche ist stabil und aktive verbundene Übungen mit dem Finger, der an seinem Nachbarn geschient ist, ergeben in einem hohen Perzentsatz vollständige Wiederherstellung der Funktion.

Bei unstabilen Bruchen ergiebt die Reposition und Ruhigstellung in *gebeugter Stellung mittels* Gipsverband sehr brauchbare Finger, aber nur wenige werden vollstandig normal. Bei den meisten findet man einen Beugeverlust und die Streckung ist fast immer im proximalen *Interphalangealgelenk herabgesetzt, häufig jedoch nur 5 bis 10°.* Wenn die Aufrechterhaltung der Stellung im Pflaster misslingt oder in schrägen kondylären Brüchen gibt die interne Fixation mit einem subkutan abgeschnittenen Draht oder einem intramedullären Spahn zufriedenstellende Resultate trotz einer Anzahl von technischen Fehlern.

Verspätung von definitiver Behandlung mittels einer der drei Methoden war eine haufige Folge von ernsthaftem Misserfolg.

In dieser Arbeit wurden die Ergebnisse gemass der *Begrenzung* von Gelenksbeweglichkeit und zuruckbleibender Verbildung beurteilt. Nur sehr selten hatte der Patient eine merkbare Funktionseinschränkung trotz eines gemass diesen anatomischen Masstaben *beurteilten* mangelhaften Ergebnisses.

COMPRESSION FRACTURE OF THE FEMORAL HEAD IN ASSOCIATION WITH CORTISONE THERAPY

By

SVEN WERNE

Osteoporosis in Cushing s disease was shown by Albright to be due to excessive production of adrenocortical steroids such as hydrocortisone Therapeutic stimulation of the adrenal cortex with pituitary adrenocorticotrophic hormone ACTH or administration of adrenocortical substances such as cortisone or hydrocortisone like substances may also produce osteoporosis

The anti inflammatory and anti allergic effect of cortisone and hydrocortisone has resulted in a wide therapeutic use of such preparations They are believed to act directly upon the tissue cells Though their mode of action is not properly understood they are believed to interfere with protein synthesis with deficient regeneration of the albumin matrix of the bone tissue The skeleton is therefore not able to absorb sufficient calcium to satisfy the requirements of regeneration of bone tissue Prolonged excess of adrenocortical substances leads to osteoporosis with the risk of spontaneous fractures The risk of such fractures is of course greater in pre existing osteoporosis resulting from disuse or ageing and in postmenopausal osteoporosis or rheumatoid arthritis

Spontaneous fractures owing to osteoporosis in rheumatoid arthritis are well known (*Baer* 1941) Since 1950 a number of spontaneous fractures have been reported in patients undergoing cortisone therapy for rheumatoid arthritis (*Boland & Headly* 1950 *Steinbrocher et al* 1951 *Boland* 1952 *Demartini et al* 1952 *de Seze et al* 1953 and others)

Spontaneous fractures have also been described in association with cortisone therapy for other diseases (*Soffer & Bader* 1952 *Teicher & Nelson* 1952 case 39221 from Massachusett General Hospital 1953 *Irwin et al* 1954 and *Eisenstedt & Cohen* 1955) The diseases in these cases were pemphigus vulgaris in 2 bronchial asthma in 2 and lupus erythematodes 1



Fig 1

In view of the relatively few publications of spontaneous fracture in association with cortisone treatment it was considered legitimate to report on a further 2 cases In addition the form of osteoporotic fracture in these two cases deserves special attention

Case 1 The patient a previously healthy farmer had been receiving corti ne for about one year because of psoriasis During this period the dosage had ranged between 50 and 200 mg a day

In June 1955 his grandchildren visited him at the hospital where he was staying He went for a walk with them in the park After strolling ab ut with them f r a

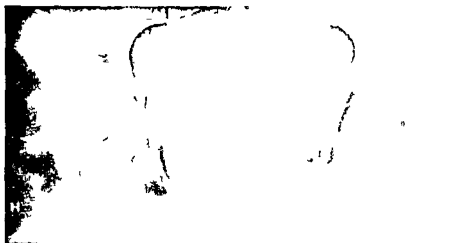


Fig 2



Fig 3

couple of hours he had such severe pain in both groins that he had to take a taxi back to the hospital

Roentgen examination of the hips gave the picture in Fig 1 Cortisone treatment was stopped but the examination was not considered to indicate any other particular treatment or instruction and the patient was sent home Follow up at the out patient department in September 19 (Fig 2) showed compression of both femoral head The patient was informed that the hip pain might have been due to previous treatment with cortisone The pain gradually became more intense and in May 19 6 and in April 1957 he was examined at his local hospital The latter examination showed further compression of the femoral head on either side (Fig 3)



Fig 4



Fig 5

and in May 1957 the patient was referred to the Orthopaedic clinic Halsingborg for investigation

Walking was obviously difficult he walked with a stoop and used two sticks The range of mobility of the both hips was markedly decreased but there was no malposition or contractures He refused operation and was therefore instructed to rest in bed at home He was re examined in August 1957 (Fig 4) when he reported that the hip pain was no longer so intense

Case 2 The patient was a housewife aged 53 who for many years had chronic polyarthritis During the last 8 years she had been treated on various [illegible]

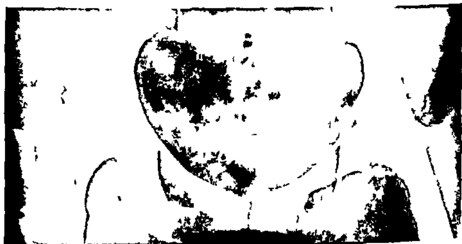


Fig 6

with cortisone Since May 1958 she had had severe pain in the left hip Examination in June 1958 revealed flexion and adduction contractures of the left hip joint and roentgenography showed severe arthrosis (Fig 5)

Arthrodesis of the left hip was done The postoperative course was complicated by polyserositis In the treatment of this complication cortisone (Kenacorte) was instituted one month after the operation After gradual withdrawal of cortisone the patient was sent home in September 1958 she was then ambulant At follow up in October the state of the joints was found to be satisfactory

In January 1961 the patient re appeared complaining of pain in the right un operated hip During the last two years she had been almost continually treated with cortisone (Kenacorte 4 mg three times daily) Roentgen examination revealed compression of the femoral head (Fig 6)

DISCUSSION

It appears that the frequency of spontaneous fractures in patients with rheumatoid arthritis has increased since the introduction of cortisone and ACTH therapy Evaluation of the significance of cortisone in the causation of such fractures in individual cases of rheumatoid arthritis is however difficult because calcium loss and osteoporosis are not uncommon accompaniments of this disease and spontaneous fractures are not rare

Stronger evidence for cortisone favouring or causing osteoporosis is therefore provided by the development of osteoporosis in association with cortisone treatment for diseases not otherwise known to be accompanied by osteoporosis such as the present case of psoriasis

Of orthopaedic and roentgenologic interest is the nature of the fracture i e compression of the crown of the femoral head which in advanced stages resembles necrosis of the head after medial fracture of the neck

Before and during the development of the fractures both patients had been ambulant and had to their knowledge not sustained any trauma capable of causing fracture of the femoral neck with subsequent necrosis of the femoral head The greatest strain to which the bone had been exposed was the vertical load when walking

Hirsch & Brodetti (1957) focused attention on the tensile strength of the proximal end of the femur and in a mechanical experimental study they were able to show that application of a certain type of pressure to the femoral neck invariably caused the same type of fracture of the neck and that a force of 400 to 1100 kg was sufficient to produce such fractures Vertical loading produced a vertical fracture in the middle of the femoral neck Fractures of this type can be excluded in the pre

sent cases. Even if detection of a fracture, if any, in the roentgenogram might have been made impossible by the rarefaction of the skeleton one would have expected demonstrable changes during the course of healing, if such fractures can heal in ambulant patients. But no such changes could be demonstrated. In addition case 1 was followed from the onset of the symptoms. Roentgen examination at that time (Fig. 1) and 4 months later (Fig. 2) showed that fracture had occurred with compression of the head during the interval between the two examinations. This shows that spontaneous fracture of the femoral head may occur in severe osteoporosis.

Greig (1931) and *Watson Jones & Roberts* (1934) stressed that osteoporosis can only develop in bones with a good blood supply to the bone substance. *Trueta & Harrison* (1953) and *Claffey* (1960) have shown that the calotte of the femoral head is supplied by a strikingly rich arterial network.

It may therefore be assumed that the demands placed on metabolism and on osteoblastic activity in this part of the head are greater than in the rest of the head and neck. Consequently impaired osteoblastic function, as in osteoporosis, will pave the way for a more rapid development of the osteoporosis with a shift of locus minoris resistentiae to weight bearing from the femoral neck to the calotte of the femoral head.

SUMMARY

Two cases are described in which unilateral and bilateral spontaneous fractures of the calotte of the femoral head occurred in association with cortisone treatment.

It is suggested that the rich vascular supply to the calotte of the femoral head is responsible for the relatively rapid advance of the osteoporosis in this region with a shift of the locus minoris resistentiae to weight bearing from the femoral neck to the calotte of the femoral head.

RÉSUMÉ

L'auteur rend compte du cas de deux malades chez lesquels, en liaison avec un traitement à la cortisone, il s'est produit une fracture spontanée bilatérale et unilatérale respectivement de la calotte de la tête fémorale.

L'auteur considère que c'est l'abondante alimentation sanguine de la calotte fémorale qui est la cause du développement plus rapide d'une

porosite osseuse d ins cette region pouvant donner lieu i un decalage de la resistance de la tete femorale a la charge du col femoral

ZUSAMMENFASSUNG

Der Verfasser berichtet uber zwei Patienten die sich im Zusammen hang mit einer Cortisonbehandlung eine doppelseitige beziehungsweise einseitige Spontanfraktur der kranialen Femurkopfkalotte zuzogen

Die reichliche Blutversorgung innerhalb der Femurkopfkalotte sicht der Verfasser als die Ursache einer sich rascher entwickelnden Osteo porose in dieser Region an Diese schafft die Voraussetzung fur eine Verschiebung des punctum minoris resistentiae wahrend der Belastung vom Schenkelhals zur Kopfkalotte

REFERENCES

Albright F Irving and Ed Brit Med J

Boland E W Clinical Use of Cortisone Hydrocortisone and Corticotropin J A M A 150 13 1281–1283 1952

Boland E W & *Headley N E* Management of Rheumatoid Arthritis with Smaller (Maintenance) Dose of Cortisone J A M A *150* 5 365–372 1950

Claffey T J Avascular Necrosis of the femoral Head J Bone & Joint Surg 42–B 802 809 1960

Curtiss I H & *Clark W S* Vertebral Fracture Resulting from Prolonged Corti one and Cortic tropin Therapy J A M A, *156* 5 467 469 1954

Demartini F *Grokoest A W* & *Ragan Ch* Pathological Fractures in Patients with Rheumat id Arthritis Treated vith Cortisone J A M A *149* 8 750–752 1952

F I Brit Med J 1 278 1955

Eisenstadt W S & *Cohen F B* O teopor i and C mpression Fracture fr m Prol nged Corti one and Corticotr pin Therap Ann Allergy *13* 3 252 256 19 5

Fischer F & *Hastrup B* Corti one and Calcium Balance Acta End rinol *16* 141 148 1954

Gr ig D M Clinical Obser ati ns n the Surgical Path l g of B ne Oliver and B yd Edinburgh and L nd n 1931

H nch Ph S *Slocumb Ch M* *Poll y H F* & *K ndall E C* Effect f C rti ne and Pituitary Adrenocortic tr pic H rm ne (ACTH) in Rheumatic Di ea J A M A *144* 16 1327 1335 19 0

Ibarra J R Jr Oste p rosi Texas State J Med 52 1 20 6 1956

Irving J T Cal ium Metal lism Methuen & Co Ltd Lon lon 19 7

Irwin J W *Henn man Ph H* *Wang D M K* & *Burrage W S* Maintenance Cor tis ne in Intractable A thma J Allergy 25 201 209 1954

Ma g lis H M & *Caplan P S* Effects of Pitu t ry Adrenoc rticotr phi Hormone (ACTH) in Rheumatoid Arthritis J A M A *145* 6 385 391 1951

Mass Gen Hosp Case 39221 New England J Med 248 27 915-949 1953

de Se e S Hubault A & Renier J C Quatre cas de fractures spontanées l er vees chez des malades traités par la cortis ne Pres e Med 39 p 819 1953

Soffer L J & Bader R Corticotropin and Cortisone in Acute Disseminated Lupus Erythematodes J A M A *149* 11 1002-1008 1952

Steinbrocher O Berkowit S Carp S Ehrlich M Elkind M Silver M & Sp t er N ACTH and Cortisone as Therapeutic Agents in Arthritis and S m Locomotor Disorders Bulletin 2 9 560-575 1951

Teicher A & Nelson C T Osteoporosis and Pathological Fractures F ll wing Treatment with ACTH and Cortisone J Invest Dermatology *19* 0 210 19

Trueta J & Harrison H M The normal Vascular Anatomy of the Fem ral Head in Adult Man. J Bone & Joint Surg *35 B* 443 461 1953

Watson-Jones R & Roberts R E Calcification Decalcificati n and O sificati n Brit J Surg *21* 461-499 1934

TRAITEMENT DES FRACTURES DU COL DU FEMUR PAR GREFFE PEDICULEE

Par

ROBERT JUDET
Paris

L incertitude des resultats du traitement des fractures du col nous a amenes a tenter depuis 1947 l association osteosynthese greffe Cette pratique a diminue la frequence des pseudarthroses mais ne parait pas influer sur les necroses avasculaires de la tete femorale

Depuis 18 mois nous utilisons une technique de reduction sanglante et osteosynthese associees a une greffe pediculee pensant que l emploi d une greffe ordinaire ne fait qu ajouter un greffon mort a l os mort de la tete femorale alors qu une greffe pediculee est vivante vasculaire et peut sans doute apporter dans le foyer et dans la tete elle meme un flux sanguin nouveau Voici comment nous procédons

– *malade a plat ventre sur notre table orthopedique*

Abord postero externe par une incision coudee comportant une branche oblique et une branche verticale La branche oblique longue d une douzaine de centimetres part du sommet du trochanter et se dirige vers l epine iliaque postero superieure la branche verticale rejoint la branche oblique au sommet du trochanter et descend sur une quinzaine de centimetres a la face externe de celui ci On dissocie les fibres du grand fessier et l on incise verticalement le fascia lata sur la face externe du trochanter

On decouvre la face externe du trochanter son bord posterieur et les muscles profonds qui recouvrent la hanche de bas en haut le carre crural les deux obturateurs et le pyramidal le moyen fessier inséres sur le bord postérieur et la partie adjacente de sa face externe C est ce bord postérieur qui va former la greffe

Le greffon doit etre epais de 15 mm au moins et comporter la partie postérieure du massif trochantérien sommet du grand trochanter et face postérieure du petit trochanter compris Son plan de coupe est un plan frontal tangent a la face postérieure du col fémoral (fig 1)

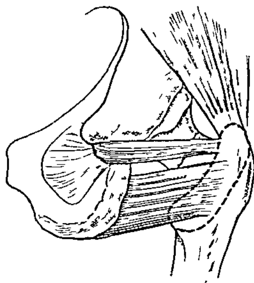


Fig. 1.
Face postérieure de l'articulation de la hanche. Le tracé en pointillé indique le plan de coupe du greffon.

Pour être sûr de prélever le greffon de l'épaisseur voulue, il est bon de découvrir au bistouri l'angle postéro-supérieur du grand trochanter en désinsérant soigneusement celles des fibres du tendon du moyen fessier qui s'y attachent. L'angle ainsi découvert, on enfonce verticalement une sonde cannelée à partir du bord supérieur de cet angle visant la face postérieure du col fémoral. Le bout de la sonde rencontre le col fémoral et on cherche à la glisser le long de sa face postérieure, ce qui est aisé. La sonde ainsi laissée en place sert de point de direction pour la coupe.

On attaque au ciseau mince de Farabeuf la corticale externe du grand trochanter en visant la sonde placée à sa face interne au ras de la face postérieure du col. On peut même, sans inconvénient, emmener avec le greffon la corticale postérieure du col sur 1 ou 2 mm d'épaisseur. Il faut aller doucement, en coupant sur toute la hauteur du trochanter par petits coups juxtaposés, sans enfoncer trop le ciseau d'un coup, de façon que la coupe soit menée sur toute sa largeur progressivement pour ne pas risquer de casser la greffe. Il ne faut pas faire levier avec le ciseau pour essayer de la détacher plus vite.

Quand la coupe est finie, on saisit avec une pince de Museux le fragment détaché, on le soulève doucement. Les muscles postérieurs profonds et la capsule postérieure se relèvent avec le greffon. Il faut couper

au ciseau la capsule en direction du bord cotyloïdien le long du bord supérieur et du bord inférieur de la face postérieure du col puis le trait de fracture et enfin la tête fémorale On place alors le greffon sous un large écarteur qu'un aide tire en dedans La face postérieure du col la face postérieure de la tête et le trait de fracture sont largement exposés et la réduction de la fracture est pratiquée sous contrôle de la vue sans qu'il soit nécessaire de faire de contrôle radiologique On procède alors à l'ostéosynthèse Nous la faisons à l'aide de deux vis de Lipmann ou de Venable qui convergent vers la partie antérieure du pôle inférieur de la tête fémorale l'une à partir de la partie haute de la face externe du trochanter l'autre à partir de sa partie basse au dessous de la crête sous trochantérienne

L'ostéosynthèse assurée reste à placer la greffe

Son lit sera constitué de dehors en dedans par la surface trochantérienne de prise de greffe la face postérieure du col avivée elle aussi le plus souvent par la prise de greffe ou sinon par l'ablation de la corticale au ciseau frappé La tête fémorale est préparée pour recevoir la greffe Pour cela nous évidons la partie postéro supérieure de la tête à l'aide d'une fraise sphérique de Doyen ne tournant pas trop vite pour ne pas chauffer On attaque la corticale du fragment céphalique à la limite du cartilage articulaire dans la concavité que présente à ce niveau la face postérieure du col Le creusement doit être conduit progressivement vers la profondeur Il doit en fin de compte évider la tête fémorale jusqu'à la partie sous chondrale On évide ainsi près du tiers postéro supérieur de la tête fémorale presque jusqu'à la face profonde du cartilage

L'extrémité supérieure de la greffe est elle aussi avivée On rugine soigneusement les débris tendineux qui s'insèrent sur elle et on en « épluche » la corticale à la pince de Liston en avivant la spongieuse

Cette dénudation ne doit porter que sur la partie de la greffe qui pénètre dans la tête Le reste du greffon reste porteur de toutes les insertions musculaires et capsulaires qui peuvent s'y trouver On fait alors pivoter la greffe de façon à enfoncer son extrémité avivée dans la tête où elle doit pénétrer à frottement mais jusqu'au fond de l'évidement préparé Dans le reste de son étendue la face cruentée de la greffe s'applique sur son lit Une vis est nécessaire pour bien la coapter Cette vis est enfoncée d'arrière en avant à travers le greffon et le trochanter jusques et y compris sa corticale antérieure (Fig 2 et 3)

Fermeture du plan du grand fessier

Le drainage aspiratif peut être nécessaire si la surface de coupe du trochanter saigne beaucoup Ce drainage sera maintenu 48 heures

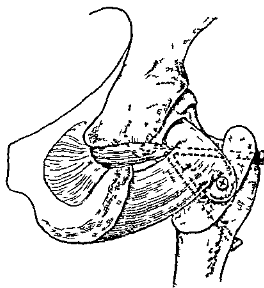


Fig 2
Le greffon en place dans le cas ou l on a conserve un pédicule inférieur

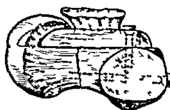


Fig 3
Coupe horizontale du col montrant la fracture reduite vissée le greffon en place avec son pédicule musculaire et sa vis de fixation

Mobilisation precoce au lit vers le 8eme jour Marche avec bequilles sans appui vers le quarante cinquiene jour appui apres controle de la consolidation de quatre vingt dix a cent vingt jours apres l intervention

Il ne peut etre question a l heure actuelle de presumer de la valeur de cette intervention Nous disposons de trop peu de cas et trop peu de recul mais il nous a paru interessant de presenter cette technique qui nous parait apporter une notion nouvelle pour le traitement des fractures du col

40 malades ont ete operes en 18 mois Ce que nous pouvons dire des maintenant c est qu en aucun cas il ne s est produit de pseudarthrose La consolidation a toujours ete obtenue meme dans des cas de pseud

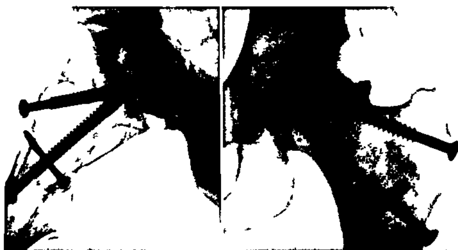


Fig 4
Fracture du col du femur Greffe pediculee (profil et face)

arthrose du col du femur ou des fractures deja anciennes datant de 2 à 4 mois au moment ou l on a fait la greffe

C est deja un point interessant qui nous parait acquis bien que cette serie soit beaucoup trop courte pour que nous puissions affirmer que la pseudarthrose peut à coup sur etre évitee ainsi Pourtant nous devons remarquer que la qualité des consolidations et l aspect radiologique du foyer de fracture apres ce type d intervention nous paraissent tout à fait differents de ce que l on observe lorsqu on utilise des modes d osteosynthese classiques C est pour nous une raison d esperer d abord que nous eviterons à l avenir les pseudarthroses ou les lenteurs de consolidation si frequentes Mais naturellement il nous est impossible de rien conclure quant à l apparition tardive de necroses aseptiques de la tete femorale Un recul de 3 à 5 ans sera nécessaire avant que nous puissions nous faire une opinion sur ce sujet

RESUME

Nous devons ajouter au point de vue indications operatoires que nous reservons ce type d operation aux malades ages de moins de 70 ans c est à dire à des gens relativement jeunes Au dela de 70 ans nous demeurons fidèles pour le traitement des fractures du col au remplacement prothetique de la tête fémorale dont les avantages chez les grands vieillards nous paraissent evidents On peut peut etre étendre l indication de

l'ostéosynthèse avec greffe pédiculée à des gens de plus de 70 ans mais dont l'âge physiologique est inférieur à l'âge légal.

Une certaine déception dans les résultats du traitement des fractures du col du fémur par les procédés d'ostéosynthèse classiques nous a conduits à envisager une intervention visant à assurer en même temps que la consolidation du foyer une réhabilitation vasculaire de la tête fémorale.

L'intervention chirurgicale consiste à prélever par voie postérieure de la hanche une greffe osseuse aux dépens de la crête intertrochantérienne postérieure en conservant toute l'attache du carré crural qui constitue un pédicule nourricier très vasculaire.

Après réduction de la fracture ce greffon est appliqué sur la face postérieure du col et fiché profondément dans la tête. Un montage métallique par vis assure la solidité de l'ostéosynthèse.

Il nous a semblé que cette pratique accélère les délais de consolidation et prévient les pseudarthroses.

Cette opération dans son principe a en outre l'ambition de prévenir les nécroses par la revascularisation de la tête mais notre série d'observations est encore trop courte pour affirmer le bien fondé de cette espérance.

SUMMARY

A certain disappointment with the results of treatment of fractures of the femoral neck by classical osteosynthesis procedures has led us to consider an operation which assures at the same time both bone fixation and restoration after vascular supply of the femoral head.

The operation done through a posterior approach involves the elevation of a bone graft from the posterior intertrochanteric crest preserving the muscle attachments which provide a blood supply.

After reduction of the fracture the vascularized bone graft is applied to the posterior surface of the neck and sunk deeply into the femoral head. Additional metallic fixation is used. It appears to us that this method accelerates union and prevents pseudarthrosis.

This operation has the further aim of preventing avascular necrosis of the femoral head but our period of observation is too short for us to state how much these hopes may be justified.

ZUSAMMENFASSUNG

Eine gewisse Enttäuschung über die Ergebnisse der Behandlung von Brüchen des Oberschenkelhalses mittels klassische Osteosyntese - Eingriffen hat uns dazu geführt eine Operation in Erwägung zu ziehen die

gleich zeitig eine Knochenfixation und eine Wiederherstellung der Gefässversorgung des Femurkopfes sichert

Die Operation welche von einem rückwärtigen Zugang ausgeführt wird umfasst die Abhebung eines Knochenlappens von der crista intertrochanterica posterior derartig dass die Muskelbefestigungen die die Blutversorgung sichern erhalten bleiben

Nach der Reposition des Bruches wird der blutversorgte Knochenspahn an die ruckwärtige Flache des Schenkelhalses gelegt und tief in den Femurkopf versenkt

Weitere Fixation mittels metallischem Material wird hinzugefugt Wir meinen dass diese Methode die Bruchheilung beschleunigt und Pseudarthrosenbildung verhindert

Diese Operation hat weiterhin das Ziel die Kopfnekrose zu verhindern aber unsere Beobachtungszeit ist zu kurz weit diese Hoffnungen in Erfullunggehen konnen

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FROM THE ORTHOPAEDIC DEPARTMENT, UNIVERSITY OF GOTHENBURG (HEAD: PROFESSOR CARL HIRSCH) AND THE DEPARTMENT OF GENERAL SURGERY, UNIVERSITY OF UPPSALA (HEAD: PROFESSOR OLLE HULTÉN)

EXPERIENCES WITH OPEN REDUCTION OF MEDIAL FRACTURES OF THE FEMORAL NECK

By

ANDERS LIDSTRÖM and OLLE THORÉN

Since the early nineteen thirties, when *Sven Johansson* published his technique of closed reduction of medial femoral neck fractures, open reduction and internal fixation have only in exceptional cases been used in the routine management of these fractures.

Whenever this treatment has been resorted to, it has invariably been indicated owing to failure by means of closed reduction to achieve an adequate apposition of the fracture surfaces permitting osteosynthesis. In view of the technical progress of the past decade, however, one wonders whether the obviousness of this indication being the only one is not about due for reconsideration.

Hulth's venographic study (1958) has introduced a more reliable method of predicting the outcome of a fracture at the time of operation. His investigation established that a negative venogram, i.e. failure of the veins draining the femoral head to be filled by the injected contrast medium, combined with a marked varus displacement, almost invariably results in more or less extensive necrosis. *S. Johansson* (1960) has subsequently reported promising results from experimental studies of the femoral head circulation by means of injections of ^{32}P.

Charnley reported in 1957 that with his so called compression screw plate the incidence of unsatisfactory clinical results could be materially reduced, i.e. from 50 per cent in earlier series using the Smith-Petersen nail to about 20 per cent in his current series. His appliance permitted compression of the fracture for a long period of time, even if a resorption occurred in the fracture site. In *Charnley's* opinion this compression achieved more than merely complete immobilization. *Trueta* has suggested that the devitalization of a narrow zone of trabeculae in both

fragments brought about by the compression may stimulate vascular activity and thereby increase the formation of new bone in the form of a creeping substitution which replaces the necrotic bone tissue in the head

Viewed against this background the questions of interest from a practical clinical point of view may be formulated as follows Can exact open reduction and a fixation based on the compression principle reduce the incidence of necrosis if examination of the circulatory function at the time of operation has indicated extensive vascular damage?

MATERIAL AND METHODS

During the period from 1957 to 1959 a total of 10 open reductions were performed at the Orthopaedic and Surgical Departments of the Uppsala University Hospital In 8 cases fixation was achieved with the Charnley instrumentarium while Nystrom nails were used in the remaining 2 cases Difficulty to obtain a satisfactory reduction was the primary indication in 4 cases In the remaining cases the treatment was adopted in an attempt to prevent the development of necrosis according to the principles outlined above

The following technique was used First closed reduction was attempted by routine methods Thereupon *Hulth's* venographic cannula was introduced through a small incision over the trochanteric region In 8 cases the reduction was adequate to permit venographic evaluation The joint was exposed by a modified lateral incision which permitted careful dissection right to the anterior capsule (*Hirsch*) In some cases this was ruptured but in the remainder it was incised along the long axis of the neck taking great care not to injure any vessels Outwards rotation provided easy access to the fracture site and no difficulty was encountered in obtaining an exact reduction Following this the fixation device was applied

In all 8 cases where venographic examination was feasible a negative venogram was obtained In the remaining two cases bleeding from the head fragment indicated that its circulation was unimpaired

The failure to obtain an acceptable result by closed reduction was in all 4 cases due to interposition In 3 cases bits of the shattered capsule were interposed partly fixing the central fragment and hampering its rotation during manipulative reduction In the fourth case a satisfactory apposition of the fracture surfaces was hampered by interposition of an avulsed fragment of bone

In the remaining 6 cases closed reduction had produced an apposition of the fracture surfaces which ordinarily could have been considered sufficient to permit fixation. Nevertheless exploration in 4 of these cases disclosed a partial interposition of capsule fragments preventing complete direct contact between the fracture surfaces.

RESULTS

In the uniform group of 7 cases in which venographs of the fracture site had produced negative results, all treated with Charnley's compression appliance, the following end results were obtained:

Healed fracture with extensive necrosis of the head – 3 patients

Pseudarthrosis and signs of necrosis of the head – 3 patients

One patient in this group died 4 months after operation from an intercurrent disease so that the results in this case could not be evaluated.

In the eighth case in which the venogram had been negative the osteosynthesis was performed with Nyström nails and somewhat more than a year after injury the fracture had united without appreciable signs of necrosis in the head.

The two fractures with apparently unimpaired circulation at the time of operation had 3 years postoperatively healed with no signs of necrosis.

DISCUSSION

The scantiness of the material does not permit any too farreaching conclusions to be drawn. Still, the results of the group with negative venograms – 6 total failures and 2 cases of uncertain results – do seem to be fairly conclusive. Even perfect reduction, achieved under visual control, and fixation by means of the compression technique had failed to influence the unsatisfactory course which could be expected. If at the time of operation the results of a venographic or autoradiographic examination of the circulation indicate the presence of extensive vascular damage, arthroplasty would seem to be a preferable alternative.

Interposition of fragments of capsule or bone was observed in a majority of these cases and in some instances was so considerable that it made an acceptable reduction impossible. Open reduction to eliminate this obstruction is the obvious treatment in fracture cases with apparently unimpaired circulation, provided the patient's condition does not directly contraindicate the more elaborate operation. The two cases

in which the fracture united suggest that this treatment has decided advantages under those circumstances. A condition for success is a cautious surgical technique in order to avoid further vascular damage.

SUMMARY

In order to see if exact open reduction and a fixation based on the compression principle could reduce the incidence of necroses and pseudarthroses by medial femoral neck fractures with signs at the operation of extensive vascular damage, 8 cases were treated in this way using a Charnley compression screw plate. The circulation was examined with Hulth's venographic method. The treatment failed to influence the unsatisfactory course which could be expected and arthroplasty would seem to be a preferable alternative in these cases.

RESUME

Afin de voir s'il est exact qu'une reduction ouverte et qu'une fixation basee sur le principe de la compression est susceptible de reduire la frequence des necroses et des pseudarthroses dans le cas de fractures medianes du col femoral presentant le signe a l'operation de lesions vasculaires etendues, 8 cas ont ete traites de cette maniere en utilisant la plaque de compression a vis Charnley. La circulation a ete controlee par la methode venographique de Hulth. Le traitement n'a pas eu d'influence sur l'evolution peu satisfaisante a laquelle on pouvait s'attendre et il semble que l'arthroplastie aurait ete une alternative preferable dans ces cas.

ZUSAMMENFASSUNG

Um herauszufinden ob eine genaue offene Reposition und eine Ruhigstellung die auf dem Prinzip der Kompression beruhte das Auftreten von Nekrosen und Pseudarthrosen bei medialen Schenkelhalsbrüchen mit Zeichen aus gedehnter Gefassversorgungsstorungen unter der Operation vermindern konnte, wurden 8 Falle in dieser Weise behandelt, indem man eine Kompressionsplattenschraube nach Charnley verwendete. Der Blutumlauf wurde mittels der venographischen Methode nach Hulth untersucht. Die Behandlung vermochte nicht den unzufriedenstellende Verlauf, den man erwarten konnte, zu beeinflussen und eine Gelenksplastik wurde in solchen Fallen augenscheinlich vorzuziehen sein.

REFERENCES

Charnley J., Blockley N. J. & Purser D. W. The treatment of displaced fractures of the neck of the femur by compression. J. Bone & Joint Surg. 39 B 45 1957.
Hirsch C. Snittforing vid collumfrakturer. Nord. Med., 67 469 1962.
Hulth A. Femoral Head Phlebography. J. Bone & Joint Surg., 40 A 844 1958.
Johansson S. Nord. Med. 63 195 1960.
Trueta J. Appraisal of the vascular factor in healing of fractures of the femoral neck. J. Bone & Joint Surg. 39 B 3 1957.

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INTERNAL FIXATION OF COMMINUTED TROCHANTERIC FRACTURES

By

FLOYD JERGESEN

Closed treatment of trochanteric fractures of the femur by skeletal traction and balanced suspension is my preference where the life expectancy of the patient is limited to a few weeks. Where open operation is not precluded by complicating systemic disease or associated injury, closed reduction by skeletal traction followed by internal fixation is elected to avoid prolonged recumbency.

Non-comminuted intertrochanteric or subtrochanteric fractures tend to be stable following anatomic reduction and generally can be fixed securely during operation by any one of many devices that are commercially available. Subsequent breakage of the apparatus or its loosening from the bone commonly does not occur provided excessive stress, such as unprotected weight bearing, is avoided until bone continuity has been restored.

Comminuted intertrochanteric and subtrochanteric fractures are likely to remain unstable even after anatomic reduction and notoriously require either prolonged traction or firm internal fixation to prevent displacement until some structural integrity is restored by initial bone healing. Internal fixation devices of current design do not provide sufficiently reliable supplemental support before bone healing is well advanced to permit unprotected weight bearing without the threat of loss of reduction or delayed healing.[2, 7, 8] These complications can follow mechanical failure of fixation as a result of either structural incompetency of the device or displacement at the interface between bone and metal.

Structural incompetency of the device can be manifest by bending, by breakage, or by seperation of its main elements.[1, 3, 5, 6, 7] The

point of failure is likely to occur at or near the apex of the angle formed by the cervical and diaphyseal segments of the device Therefore a high factor of safety is desirable at this juncture

This report summarizes observations gathered during the past 1? years from a small series of patients with comminuted trochanteric fractures who have been treated by internal fixation with a heavy plate and nail device

CLINICAL MATERIAL

Fifteen comminuted trochanteric fractures in patients whose ages varied between 39 and 88 years were selected for treatment There were two general criteria of selection (1) that alternative closed treatment which might require prolonged immobilization of the patient was undesirable and (2) that there was comminution

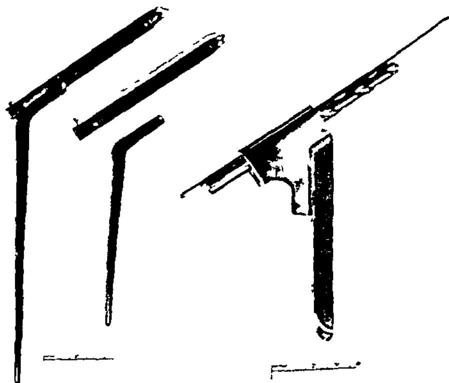


Fig 1 Fig ?

Fig 1 Ph t graph f the "T" beam nail and 2 sizes of plate
Fig ? Ph tograph f the jig u ed to facilitate application f the fixati n apparat s

APPARATUS

Two main elements a nail and a plate (Fig 1) comprised the internal fixation device used in treatment of these patients The length of the nails varied in one fourth inch increments from 3 to 5 inches The cross section of the shaft of the nail was a T modification of the familiar I beam structural design The base of the nail accepted a one-fourth inch 4/24 thread of the common surgical nail driver When completely seated in the plate a small setscrew in the base of the nail engaged a pit in the plate to prevent disengagement of the two elements

The plates were of two lengths the diaphyseal segments measured either 4 or 6 inches The longer plates accepted six and the shorter four standard bone screws The angle between the cervical and diaphyseal segments was either 125 or 135 degrees The cervical segment of the plate had a keyway to accept the bottom flange of the nail Because of close tolerance of manufacture the apparatus became semirigid whenever it was assembled with the setscrew tightened

All devices were made of Type 317 steel except four which were made of commercially pure titanium metal[4]

A special jig facilitated insertion of the device at the time of operation (Fig 2)

POSTOPERATIVE TREATMENT

If there was no conflicting circumstance the patient was permitted to sit in a wheelchair within a few days after operation Only this activity was advised for those of the older age group until there was x ray evidence of bone continuity across the fracture clefts Generally it was the order of 5 or 6 months after operation that partial weight bearing was instituted and subsequently increased by graded increments Only the most agile patients in the fourth and fifth decades were encouraged to use crutches without weight bearing prior to restoration of bone continuity

COMMENTS

No postoperative infection occured among the patients of this small series There was no death in the six months period after operation

A single example of mechanical failure of the device manifest by breakage of screws was thought to be caused by unsupported weight bearing prior to firm healing of the fracture Refixation of the fracture was necessary



Fig 3

a October 17 1950 A 68 year old female A comminuted intertrochanteric fracture fracture of the femur associated with bone atrophy

b October 24 1951 One year after closed reduction and internal fixation Bone continuity has been restored but tubulation was not complete since the cortex and medullary cavity had not been reconstructed

c November 20 1957 Seven years after operation and one and one half years after removal of fixation apparatus Tubulation was complete but deformity of the greater trochanter persisted because of inaccurate reduction





Fig 4

a May 8 1954 A 6? year old male A comminuted intertrochanteric fracture
b July 19 1954 Two months after closed reduction and internal fixation of the fracture The lesser trochanteric fragment was inaccurately reduced
c November 5 1958 Four and one half years after operation Incorporation of the trochanteric fragment on the osseous mass medially supplied needed structural support to this important area

Atrophic bone associated with post menopausal osteoporosis provides poor anchorage for any internal fixation device (Fig 3) If the apparatus remains firmly attached until bone continuity has been restored the device may add structural integrity during that prolonged period necessary for tubulation to be completed (Fig 3b and 3c) Deferment of removal of internal fixation apparatus until this late phase of healing



Fig 5

a August 0 1954 A 39 year old male A comminuted trochanteric fracture after weeks of treatment by skeletal traction Although fair reducti n had be n b tained it was feared that healing might be delayed

b January 4 1955 Five months after pen reducti n and internal fixati n I ne continuity had been incompletely restored alth ugh it was sufficientl ad anced to permit weight bearing with ut support

c February 3 195 S n after a fall down a flight f tep in which a subcapital fracture wa sustained There was no mechanical failure f the fixati n appara or displacement of the trochanteric fracture



Fig 6

a April 4 1960 A 66 year old male A comminuted trochanteric fracture after 3 months of treatment in skeletal traction Only fibrous healing was present and continued traction was necessary to prevent varus deformity

b October 19 1960 Six months after internal fixation The patient was bearing weight unsupported The fracture cleft was still visible and healing was incomplete

has been accomplished may prove to be a significant factor in reducing the incidence of refracture

Even though desirable anatomic replacement of the lesser trochanteric fragment was not always feasible (Fig 4) This important segment can add stability during the early phase of healing and ultimately can provide added structural solidarity to the healed bone Although accurate anatomic replacement may not be possible approximation of the fragment to the site of the defect and prolonged support of the cervicocapital fragment in relation to the major diaphyseal fragment by adequate fixation apparatus can aid in restoring structural integrity (Fig 4b and 4c)

Extensive comminution (Fig 5a) can require supplemental fixation by either transfixion screws (Fig 5b) or a second plate to obtain rigidity or to assure approximation of intermediate fragments Rigidity of fixation and initial bone healing can provide sufficient structural solidarity that subsequent trauma will cause fracture at a location other than the original site (Fig 5c)

Occasionally internal fixation must be deferred until some complica

ting factor has been rectified. Where prolonged skeletal traction is necessary to prevent deformity, it can be a factor in abetting delay of healing (Fig. 6a). Late internal fixation can provide rigidity of support to the fracture fragments allowing the patient to be mobilized while healing progresses (Fig. 6b).

This heavy "T"-beam nail and plate device also has been used for fixation after subtrochanteric osteotomy in adults.

Loosening at the interface with migration of the nail through the head of the femur was not encountered in these patients. Absence of this complication was attributed to avoidance of weight bearing until preliminary bone healing had been evident by radiographic examination.

SUMMARY

Observations gathered during a 12 year period following treatment of 15 comminuted trochanteric fractures by internal fixation with a "T"-beam nail and heavy plate are summarized. The fixation device was designed to provide a high factor in safety near the apex of the angle formed by its cervical and diaphyseal segments. Weight bearing was not advised until restoration of bone continuity by initial healing was considered to be present by radiographic examination. Mechanical failure of fixation was encountered only once and was manifest by breakage of screws used to fix the plate to the femoral diaphysis. Failure in this patient was attributed to weight bearing prior to restoration of bone continuity.

ACKNOWLEDGEMENT

I am indebted to Mr. Henry Rafael, Jr., the photographer.

RÉSUMÉ

Compte rendu sommaire d'observations recueillies durant une période de 12 ans ayant suivi le traitement de 15 fractures trochantériennes broyées par fixation interne au moyen d'un clou en forme de tige en T et de fortes plaques. La formule de fixation était apte à assurer un facteur élevé de sécurité à proximité du sommet de l'angle formé par les segments cervical et diaphysaire. La charge du corps n'est pas conseillée avant qu'un examen radiographique ait montré le rétablissement de la continuité de l'os par guérison initiale. Un défaut mécanique de fixation n'a été constaté que dans un cas et s'est manifesté par la rupture des

vis utilisees pour la fixation de la plaque a la diaphyse femorale L echec du traitement chez ces malades fut attribue a la charge du corps avant le retablissement de la continuite de l os

ZUSAMMENFASSUNG

Beobachtungen die während einer 12 jährigen Zeitspanne nach Behandlung von 15 trochantären Splitterbrüchen mittels innerer Fixation mit einem "T" Balken Nagel und einer starken Platte gesammelt wurden werden zusammengefasst Die Ruhigstellungsvorrichtung wurde konstruiert um einen hohen Sicherheitsgrad in der Nähe der Spitze des Winkels der von ihrer cervicalen und Diaphysensegmenten gebildet wird zu geben Belastung wurde nicht gestattet ehe nicht Röntgenuntersuchungen die Wiederherstellung der Knochenkontinuitet durch beginnende Heilung nachweisen konnten Mechanisches Versagen wurde nur einmal angetroffen und wurde durch den Bruch der Schraube die zur Befestigung der Platte an der Femurdiaphyse verwendet worden war angezeigt Der Versager bei diesem Patienten wurde der Belastung vor der Wiederherstellung der Knochenkontinuitet zugeschrieben

REFERENCES

1 *Cleveland M Bosworth D M & Thompson F R* Intertrochanteric Fractures of the Femur J Bone and Joint Surg 29 1049 1067 1947

2 *Cleveland M Bosworth D M & Thompson F R* Trochanteric Fracture J AM M A s 137 1186–1190 1948

3 *Evans E M* The Treatment of Trochanteric Fracture of the Femur J Bone and Joint Surg 31 B 190–203 1949

4 *Jergesen F H* The Use of Titanium Prosthetically in Orthopedic Surgery Rem Cru Titanium Review 9 6 8 1954

5 *Murray R C & Frew J F M* Trochanteric Fractures of the Femur J Bone and Joint Surg 31 B 204 219 1949

6 *O Brien R M Shy J C & Bublis N J* Internal Fixation of Trochanteric Fracture of the Femur J Bone and Joint Surg 28 791–797 1946

7 *Ramadier J O Duparc J Rougement D & de Ferrari C* Le Traitment Chirurgical Des Fractures Trochanteriennes et Juxta trochanteriennes Rev Chir orthop Par 42 759 787 1956

8 *Schumpelick W & Jantzen P M* A New Principle in the Operative Treatment of Trochanteric Fractures of the Femur J Bone and Joint Surg 37 A 693–698 1955

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HEAD: M. FELLÄNDER

ARTHROPLASTY WITH MOORE PROSTHESIS FOLLOWING FEMORAL-NECK FRACTURE

By

M. FELLÄNDER and B. WALLDIUS

At the Orthopaedic Clinic, St. Görans Hospital, over a seven-year *period (1955–1961) 68 arthroplastic operations by Moore's technique* were performed for fracture of the femoral neck and its residual conditions. 90 % of the patients were women. The higher age groups predominated. The average age was 69 years, the oldest patient was 89 and the youngest 45 years old.

Indications for Operation:

1. Irreducible fractures (16 cases).
2. Early displacement of the fracture after nailing (10 cases).
3. Pseudarthrosis (38 cases), and
4. Avascular necrosis of the femoral head accompanied by pain and difficulty in walking (14 cases).

Bed rest after the operation was about 3 weeks. Length of hospital care was in 6 cases just under 4 weeks and in the great majority (41 cases) 6–8 weeks.

35 cases were followed up with an observation period of 2–6½ years.

The mortality was 4/68 (6 %), referring to patients aged 81, 82, 76 and 74 years, diagnosed as circulatory insufficiency, marasmus plus decubitus (2 cases), and hemiplegia respectively.

Complications in immediate connection with the operation were subluxation (1 case), subluxation plus fracture of the lesser trochanter (1 case) and the stem of the prosthesis perforating the cortex (1 case). Further complications occurring later included luxation plus infection (1 case), thrombosis (4 cases) and wound infection (3 cases). In 6 of these 11 cases the endresult was good in spite of the complications.

At the follow-up Shepherd's scheme was used to evaluate the result. The scheme included a gradation of

1 the functional capacity
2 the degree of pain in accordance with Merle D Aubigne s scheme
3 the mobility determined by Gade s index in which the movement paths which are more important for function are graded higher than others and finally
4 the patient s own evalution

The results were then estimated as very good and good in 77 % a figure which agrees very well with the patient s own opinions

As regards pain, 45 % stated they were quite free from aching and walking pain If we add those who had slight intermittent pain and pain only when tired quickly disappearing when resting this figure is brought to 80 %

The mobility in almost all cases remained good All except one could put on shoes and stockings themselves

In 40 % as the cases Trendelenburg s sign was negative and the patients walked without a limp Four patients walked with 2 crutches In 45 % there was no shortening of the leg as measured from the iliac *spine to the medial malleolus*

A good estimate of the functional capacity is obtained from the manner in which these old people manage in their social milieu 50 % of the patients live alone in one room with a kitchen or kitchenette They look after their small homes themselves do their own shopping and need no assistance in buses and trams Four live in a pensioners home and are relatively easy to look after

With regard to the subsequent course 3 patients have had a deteriora tion while in the others the condition has remained stationary

No prosthesis fracture has been recorded The position of the pros thesis in the bone seems to be stable but the question is whether or not the prosthesis in these old people with osteoporosis may work loose after a few more years So far we have seen 2 cases in which X ray showed that the prosthesis was loose but in which the result was still good In one of these the prosthesis had sunk into the femoral shaft and had an enlarged clear zone around the intramedullary stem and in the other case the prosthesis was seen pumping up and down some millimetres in the medullary cavity Another complication was a cen tral atrophy in the acetabulum very pronounced in 1 case and sug gested in 2 In these cases a prosthesis with a head of too small diameter had been used A slightly increased sclerosis of the acetabulum was recorded 4 times In most cases the prosthesis seemed to be firmly anchored there was no enlargement of the channel around the intra

medullary stem and there was increased sclerosis around it and in the upper window on the stem. This observation was verified by the autopsy findings in one case. The patient had been operated on 2 years and 4 months earlier. Solid bone plugs had grown through the window of the prosthesis which was absolutely firm. A smooth thin fibrous tissue surrounded the prosthesis.

Naturally, longer observation period and larger series are necessary before a final assessment of the method can be made, but at present it seems to be the method which is the least ordeal to these old and frail patients.

SUMMARY

Over the 7 year period 1955–1961, 68 Moore arthroplasties were performed on a group of mainly female patients. The mortality was 6 %. Good results – both subjectively and objectively – were obtained in 77 %. Freedom from pain and a considerable relief of pain were obtained in 80 %. Mobility in the hipjoints was adequate in almost 100 % of the cases.

RESUME

Durant une période de sept ans, 1955 à 1961, il a été pratiqué 68 arthroplasties selon la méthode Moore principalement chez des femmes âgées. Mortalité 6 %. Bons résultats aussi bien subjectivement qu'objectivement chez 77 %. Abolition des douleurs ou soulagement essentiel dans 80 %. Mobilité de l'articulation entièrement bonne dans pratiquement 100 % des cas.

ZUSAMMENFASSUNG

Während einer Siebenjahrszeitspanne 1955–1961 wurden 68 Mooreplastiken in einem überwiegend älteren weiblichen Klientel ausgeführt. Die Sterblichkeit war 6 %. Ein sowohl subjektiv als auch objektiv gutes Ergebnis wurde in 77 % erzielt. Schmerzfreiheit und wesentliche Schmerzlinderung wurde in 80 % erhalten, gute Beweglichkeit im Gelenk in beinahe 100 %.

"I have neither pain nor any trouble at all. I consider I am completely cured" (male patient 72 years of age, writing two years after operation). Another one wrote: "before the operation I could hardly walk 100 meters and could not do my housework. Now I walk about all day and do all my housework" (female patient 25 year old, 25 months after operation). Another one: "I am very pleased. Except on occasions there is practically no pain and this cannot be compared to what I suffered before the operation" (32 year old female patient, twelve months after operation). Another one: "I am very pleased. I have no pains and lead a normal life. I have more mobility than before the operation" (49 year old female patient, 28 months after operation). Yet another: "I am very pleased. I have still some pain but nothing in comparison to what I suffered before operation" (15 year old male patient, 29 months after operation).

We have operated quite indiscriminately as regards type of process, size of lesions and age of patient. In some cases where the disease was in the first stages there was either no improvement at all or this was just temporary, whilst in other cases where very pronounced lesions were found the pain either disappeared completely or almost completely.

About two years ago we changed our technique and now add osteotomy of the major trochanter as commended by *Brandes* and muscular section of the fascia and adductors as advised by *Voss* to the metaphyseal curettage. In some cases we add tenotomy of the iliac pso... accordance with *Pauwels's* technique to produce a temporary ... of the hip.

We must admit that the good results obtained with this ... have surprised us, it being noteworthy that pain has ... 90 % of the cases. Pain is reduced to a greater or lesse... cordance with each case, but even in those cases w... remains, this is very little and our patients are very ... the results.

We have operated on only 50 cases, and natural... until we have a greater number of cases and mo... after operation these results are of only relative va...

However, we have no hesitation whatsoever in ... operation to our patients as the first operation ... osteotomies, arthrodesis, arthroplasties, resectio... those cases where the results are unsatisfactory.

The fundamental idea in the treatment of

to relieve pain Progressive functional limitation even when pronounced does not bother the patients too much so long as they have a certain amount of flexion as is generally the case and always supposing the disease is not bilateral

The inconstant and temporary results of the *Camitz* and *Tavernier* types of denervations and *Duvernay s* perforations have prompted us to abandon these as have most other orthopaedic surgeons

For this reason in those cases where the operation we have described is a failure we prefer wherever possible and when abduction and adduction of the hip permits to do a *Pauwels* type osteotomy our opinion is that the best one is the varus angulation osteotomy We have often wondered whether the improvement produced by this cannot be due to the same reason as the *Brandes* and *Voss* operations or that recently proposed by *MacFarland* i e with the varus angulation and the drawing together of the insertion points of the periarticular muscles there is temporary laxity of the hip

We indicate arthrodesis in those cases where the patient is young and needs to work and walk and where the result of the operation has not been very satisfactory or where pain has returned and the disease is unilateral

This operation gives very good results a great many of them have been performed and among others *Watson Jones* experiences are worth mentioning With the exception of a reduction in joint movement the patients remain well have a solid and painless hip which permits them to walk and work much better than when an arthroplasty has been performed

Our technique for arthrodesis is as follows *Gibson s* incision with a chisel the throchanter is sectioned obliquely near to the base the capsule is opened the head is dislocated and the intra articular cartilage of the head and acetabulum is removed The head is replaced and the joint fixed with a three phlange Smith Petersen nail or a two phlange Valls nail Bone chips are placed around the joint line and then the fragment of trochanter is placed conserving the muscular insertions as a bridge between the neck of the femur and the iliac bone which have been previously fish scaled fixing it in that position

We believe that this graft of pediculated trochanter has more vitality than a free graft It is fixed in place quicker and helps to form a bone bridge in a shorter space of time

Should the general condition of the patient not allow for such a big operation we use *Watson Jones* technique the insertion of a nail to

fix the joint, which is a quick operation with which quite good results are obtained. The pain usually disappears though coxo-femoral bone fusion is not always obtained.

Nevertheless, there are some persons who are frightened at the idea of a loss of movement and will not accept arthrodesis. In these cases it is necessary to perform arthroplasty.

Other patients have lesions in the other hip, or rigidity of the lumbar vertebrae or repeated lumbalgias. For these patients arthrodesis is not recommended and arthroplasty is indicated.

In old age patients, or in those cases where the general condition leads one to surmise that the patient will not live for long, it is preferable to perform an arthroplasty.

Arthroplasty can also be performed on those cases where the patients are relatively young, in good economic position, or who lead sedentary lives, who have no lesions in the acetabulum, and who wish to have a movable hip that is painless, and also on those whom, in case of an unsatisfactory result, an arthrodesis can be performed later.

It is now accepted that the metal or acrylic prosthesis with intramedullary stem gives the best results, but these are not constant and it requires more experience and a more prolonged study before the percentage of good results can be established.

At the present time a satisfactory result can be expected, that is a hip with some movement and with little pain in 60 % of the cases.

We should not forget that a person who has had an arthroplasty of the hip is, with a few exceptions, generally an invalid to a greater or lesser degree, who must use a stick for support, who cannot walk very far, and who is troubled by more or less constant pains.

There is also a question of the behaviour of the acetabulum under the constant rubbing of the acrylic or metal head.

Late lesions of the acetabulum, consisting of juxta-articular tracings in the weight bearing area, which gradually become larger and deform it, have been found, together with a wearing away of the bottom of the acetabulum, producing something similar to protrusion of the acetabulum.

SUMMARY

To sum up, when we have a case of arthrosis deformans of the hip we first perform our combined *Metaphyseal curettage and temporary laxity operation* and leave the other operations, osteotomy, arthrodesis, arthroplasty, etc. for those patients where pain recurs.

RESUME

Pour resumer lorsque nous avons un cas d arthose deformante de la hanche nous essayons premierement une operation combinee de curetage metaphysaire et d opération de laxite temporaire en repous sant les autres interventions osteotomie arthrodese arthroplastie etc au moment ou les douleurs reapparaitraient chez ces malades

ZUSAMMENFASSUNG

Zusammenfassend kann man sagen dass wir in Fallen von Arthrosis deformans der Hufte zuerst unser kombinierte *Metaphysenauskratzung und vorubergehende Erschlaffungsoperation* ausfuhren wahrend wir die anderen Operationsmethoden wie Osteotomie Arthrodese Gelenks plastik etc fur jene Patienten reservieren bei denen Schmerzen wieder auftreten

REFERENCES

Adam A & Spenc A J Intertro hanteric osteotomy for o teoarthritis of the hip J B ne Joint Surg *40–B* 219 226 1958

Blount W P Blade plate internal fixation for high fem ral oste t mies J Bone J int Surg 25 319 339 1943

Camb ll J P & Jackson J P Treatment f osteoarthriti f the hip by oste tomies J B n J int Surg *38–B* 468–474 19 6

C rli r C Liyani F & Carnier H A pr po le 50 chanche pendante temp raire d après la techn que de V s modifiee Rev Rhum et de Malad O te Artic 27 337 1960

Jackson Burrows H Di placement te t m f r c teoarthriti f the hip Re ults more than ten year later J Bone J int Surg *37B* 1C8 1355

Malkin S A S Femoral ste t my in treatment of st arthriti of the hip Brit Med J 1 p 304 1936

McMurray T P O te arthriti f the hip joint J B ne J int Surg *2/* 1 11 1939

Nissen K Communicati n per nelle 1958

O born C V C Fahrni W H Oblique di placement te t m f r te rthriti of the hip joint J Bone Joint Surg *32B* 148 165 1950

Pauwels Fr De affection de la hanche d origine mécanique et de leur traitem nt par l téct mie d adduction Re Chir Orthop 37 22 30 1951

Pauwels Fr Directi es n uvelles p ur le traitement chirurgical de la c x rthr Rev Chir Orthop 45 681 1959

Trueta J C n idération on the path logy of oste arthritis f the hip Congre S c Int rn Orthop Barcelone 1957

Valls J Curetead metafi ari en la arthro is deformante de la ca lera (en c la b ración con lo Dre Domingo Mu c I s Hector F Piatigor ky) B l Tral S c Arg Orth p Traumatol Bueno Aire 26 12 1961

Valls J Late treatment of post traumatic aseptic necr i of the hip in fractures and dislocati ns of the neck of the femur with special reference to arthrodesis and arthroplasty Wiederherstellung chirurgie und Traumat ? ge Basel 5 74 1960

Voss C Coxarthro e operation palliative simple Münch Med Woch 9? 9 ? 9 ? 39 1058–1101 1956

Voss C Die temporare Hangehüfte – ein neues Verfahren zur operativen Behandlung der Koxarthrose und anderer deformierender Hüftgelenkserkrankungen Verhandlung der Deutschen Orthopädischen Gesellschaft 43 Congress 19 ? 351

Watson Jones R & *Robinson W C* Arthrodesis of the osteoarthritic hip Joint J Bone Joint Surg., 38 B 353 1956

FROM SOPHIES MINDE OSLO UNIVERSITY ORTHOPAEDIC HOSPITAL
HEAD PROF DR MED IVAR ALVIK

ARTHRODESIS OF THE HIP

A method allowing weightbearing and walking postoperatively

By

IVAR ALVIK M D

Hip fusion for unilateral disabling hip lesions has for a long time been accepted as one of the best procedures to restore working capacity particularly in heavy workers The anchylotic hip permits an excellent gait especially in younger individuals with a mobile lumbar spine and is usually also rather well suited for the ordinary sitting position provided that the hip is anchylotic in the functional best position In our experience *the functionally best position is about 25 degrees flexion 10 5 degrees adduction and a few degrees external rotation*

The disadvantages of the hip fusion have been

1 Long lasting recumbency with one or both hips immobilized in a big plaster spica
2 A rather high frequency of pseudarthrosis after the operation

To avoid or minimize these disadvantages we have tried to develop a method giving so complete internal fixation that

1 The patient could be let out of bed and allowed walking a few days after the operation
2 A short spica not extending below the knee is sufficient for external immobilization allowing free mobility of the knee and ankle
3 The patient can take care of himself and be active during the time of convalescence
4 The frequency of pseudarthrosis could be reduced

The method of Watsen Jones using the long Smith Petersen nail yields a good fixation but not strong enough to satisfy the requirements stated above This new method consists of a "two point fixation using

Valls J Late treatment of p t traumatic a eptic necrosi f the hip in fr t r s and disl cati ns of the neck of the femur with pecial referen e t ar r de is and arthr pla ty Wiederherstellung chirurgie und Trauma l g Basel 5 74 1960

Voss C Coxarthrose operati n palliative simple Munch M d W ch 51 4 9 6 35 1058 1104 1956

V ss C Die tempo rare H ngehüfte – ein neue Verfahren zur pera iven Beh n lung der h xarthr e und anderer def rmierender Huftgelenk erkrank gen Verhandlung der Deut chen Orth padi chen Ge ellschaft 43 Congre 195 351

Wats n Jones R & Robins n W C Arthrode is of the osteoarthritic hip J J Bone Joint Surg., 38 B 353 1956

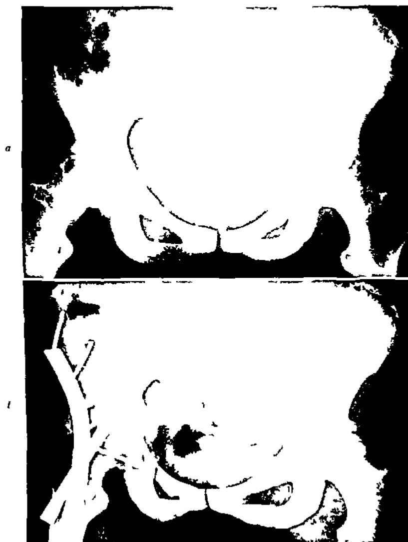


Fig 5

Osteoarthritis of the right hip

Before operation
4 months after the arthrodesis Walking and weightbearing started a few days after the operation

the anterior lateral part of the ileum the hip joint the upper part of the femur with the neck and the greater trochanter are exposed One disadvantage with this exposure is that the gluteal nerve branch to the

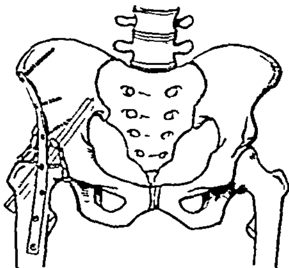


Fig 1

a long Smith Petersen nail (Watson-Jones) driven into the ileum up to the sacro-iliac joint and in addition *a strong Vitalium plate individually shaped during the operation and placed on the anterior surface of the femur extending upwards along the anterior edge of the ileum including spina ilei sup* The screws through the plate into the ileum entering from the anterior edge of the ileum are placed *between the internal and external lamina* of the ileum The hold obtained in this way is a very good and stable one

The fixation between the femur and the pelvis is so complete that the patient can be placed back in bed and be allowed out of bed walking and weightbearing without any plaster cast The patient feels however more secure with a cast and the nursing staff find the postoperative treatment more convenient with a cast so that the patient is fitted with a short plaster spica just after closing the wound This short spica allows free mobility of the knee and ankle joint on both sides *The patient is let out of bed in the course of the first 3 4 days after operation allowing walking and weightbearing*

The incision used is an anterolateral starting just above the spina ilei ant sup extending downwards laterally slightly posteriorly curved placed a little anteriorly to the greater trochanter and extending far enough down on the lateral side of the femur to allow driving in the Smith Petersen nail The tensor fascia lata is divided from the gluteal muscles and retracted medially and the proximal lateral part of vastus lateralis is separated from the upper part of the femur In this way

ver rather unimportant In most cases an ordinary internal resection of the hip joint should be done but in cases with a narrow joint space an internal resection is unnecessary

By means of this method it is rather simple to do a hip fusion also after an unsuccessful intramedullary and Judet prosthesis Bone material to fill up the gap between the remaining part of the neck and the acetabulum can be taken from the trochanter region from the iliac crest and/or from the bone bank

The short spica is worn for 4 months during which the patient is allowed weightbearing and the usual social activities at home or at a convalescent home After that the lumbar spine gait is trained

Until now 93 hips have been fused by means of this new method The first 41 before Dec 1960 have been followed up All of them healed completely without developing pseudarthrosis but in 5 cases the short hip spica had to be worn for more than 4 months There was no death no serious infection and no other bad complication All of them had been given anticoagulation treatment prophylactic from the day of operation (After this follow up we had two infections which in one case required removal of the nail and two fractures of the femur some time after the plaster spica was removed) Among the 70 preceding arthrodeses fused by means of various other methods 7 resulted in pseudarthrosis

SUMMARY

A new method for hip fusion is described The internal fixation in this method is strong enough to allow weightbearing and walking in the postoperative period starting a few days after the operation wearing only a short spica allowing free mobility of the knee joint The internal fixation consists of a long Smith Petersen nail and in addition a strong vitallium plate shaped individually during the operation placed anteriorly and fixed to the anterior edge of the ileum and the anterior side of the femur The short spica is worn for 4 months with the patient sharing in the usual social activities The follow up of the first 41 operated upon in this way shows very satisfactory results

RÉSUMÉ

Une nouvelle méthode de fusion de la hanche est décrite La fixation interne par cette méthode est assez forte pour permettre la charge du corps et la marche dans la période post opératoire qui commence peu de

jours après l'opération en portant seulement un court spica permettant *la mobilité de l'articulation du genou.* La fixation interne est effectuée au moyen d'un long clou Smith Petersen et d'une forte plaque de vitallium modelée individuellement pendant l'opération, placée antérieurement et fixée au bord antérieur de l'os ileum et au côté antérieur du fémur. Le court spica est porté pendant une période de quatre mois, le malade prenant part à ses activités usuelles.

L'observation suivie des 41 premiers cas opérés selon cette méthode ont montré que des résultats très satisfaisants avaient été obtenus.

ZUSAMMENFASSUNG

Eine neue Methode der Hüftarthrodese wird beschrieben. Die innere Fixation bei dieser Methode ist stark genug, um das Belasten und Gehen in postoperativen Periode zu gestatten. Der Patient beginnt damit nur wenige Tage nach der Operation mit einer kurzen Gipshose, die freie Beweglichkeit des Kniees erlaubt. Die innere Fixation besteht aus einem langen Smith Petersen Nagel mit Hinzufügung einer starken Vitalliumplatte, die individuell während der Operation geformt, vorne angelegt und am vorderen Rande des os ileum und an der Vorderfläche des Femurs befestigt wird. Die kurze Gipshose wird 4 Monate getragen, während welcher Zeit der Patient seinen gewöhnlichen Beschäftigungen nachgehen kann. Die Nachuntersuchung der ersten 41 Patienten, die in dieser Weise operiert wurden, zeigt ein sehr zufriedenstellendes Ergebnis.

FROM SVENSKA RIKSIDROTTSFÖRBUNDETS POLIKLINIK STADION
STOCKHOLM

FOLLOW UP RESULTS OF MENISCECTOMY WITH REGARD TO THE WORKING CAPACITY

By

OLOF PERES

Meniscectomy at meniscus ruptures has produced good results and numerous follow up studies the results have been satisfactory in 0 to 90 % of the cases It is further known that extirpation of the me ial meniscus gives better results than extirpation of the lateral one ue to these studies the indications have widened It is especially from Anglo American quarters maintained that repeated exudates and ockings give rise to arthrosis why active treatment is recommended oung athletes are often subjected to meniscus injuries and the sur eon is repeatedly faced with the question can I go on competing ? t is known that a youth who has been operated on can very well com ete for 10 years without being troubled by the knee but in the long un will his knee be damaged by continuing the sport?

To get an answer to this question I made a follow up study on men operated at the Karolinska Army Hospital and at the Department of urgery Serafimer Hospital during the years 1930 to 1934 There were total of 68 men Of these I found 35 (2 were dead) Most of them ere doing their military service at the time and it was difficult to ocate them afterwards They are living in different parts of the coun ry They were handed a detailed questionnaire The men were at the ie of operation between 18 and 42 years of age 27 were between 8 and 25 years old

From the hospital records it appeared that the anamnesis showed no nown trauma in 5 cases 2 had been hit directly on the knee and 7 stepped amiss during work The remaining 19 were accidents uring athletics (gymnastics 7 jumping 6 ball games 2 running encing wrestling and skiing 1 each)

jours après l'opération en portant seulement un court spica permettant la mobilité de l'articulation du genou. La fixation interne est effectuée au moyen d'un long clou Smith Petersen et d'une forte plaque de vitallium modelée individuellement pendant l'opération placée antérieurement et fixée au bord antérieur de l'os ileum et au cote antérieur du fémur. Le court spica est porté pendant une période de quatre mois le malade prenant part à ses activités usuelles.

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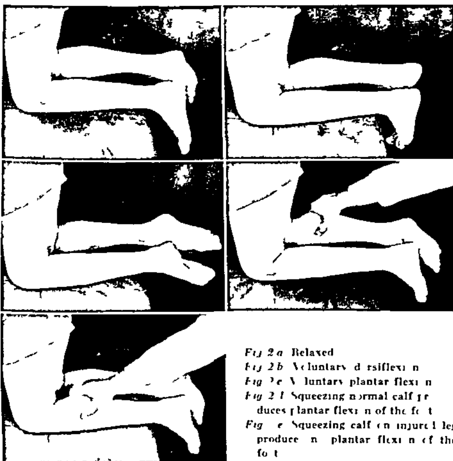


Fig 2 a Relaxed
Fig 2 b Voluntary dorsiflexion
Fig 2 c Voluntary plantar flexion
Fig 2 d Squeezing normal calf produces plantar flexion of the foot
Fig 2 e Squeezing calf on injured leg produces no plantar flexion of the foot

Fig 2
Photos of a typical case of ruptured tendo achillis

SUMMARY

1 A test for rupture of the tendo achillis is described
2 The diagnosis of this injury is frequently missed or delayed
3 Early repair of such a rupture is much more satisfactory than late repair
4 For these reasons this test should be employed not only to confirm the diagnosis but also to convince the patient that surgical repair is indicated



Fig 1a
Squeezing calf produces plantar flexion of foot when tendon is intact

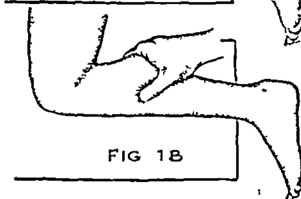


Fig 1b
Squeezing calf produces no motion of foot in injured leg

rupture of the tendon of achilles seen at three New York Hospital and in twenty two the diagnosis was not made by the first examining doctor. Other authors have reported that the diagnosis of rupture of the tendo achillis is frequently missed because the patient can actively dorsiflex and plantar flex the foot.

There are many interesting facts about these forty seven patients with ruptured heel cords which could be reported.

Numerous methods of repair recommended by various authors have been reviewed (. 6 7 8 12 14 20 21)

The Bunnell pullout wire that is tied outside of a cast which holds the foot in equinus until healing is complete is in our opinion the best method of holding the tendon ends together while healing takes place.

Because early repair is fairly simple and late repair very difficult it is hoped that the use of this simple test will be helpful in making a prompt diagnosis and instituting early surgical treatment.

10 *Hierton T* A simple method f diagnosing rupture of the achilles tendon Svensk kirurgisk Forenings forhandl *17* 50–51 1959

11 *Hierton T* A simple method of diagnosing rupture of the achilles tendon Nordisk Medicin *63* 671–672 1960

12 *Lawrence C H Cave F F & O Connor H* Injury of the achille tend n ex perience at Massachusetts General H pital Am J Surg *83* 795 800 19 5

13 *Lindholm A* A new method of operation in subcutane u rupture of the achilles tendon Acta chir scand *117* 261–270 1959

14 *McLaughlin H L* Repair of major tendon ruptures by buried rem vable su tures Am J Surg *74* 758 1947

15 *Quigley T B & Banks H* Progre s in the treatment of fractures and disl ca tions W B Saunder Phila p 66 1960

16 *Scott J H S* Pitfalls in the management of sp rt injurie Practiti ner (L n don) *185* 770–779 1960

17 *Silfverskiold N* Uber die subcutane t tale Achillessehnenruptur und deren Behandlung Acta chir cand *84* 393 1941

18 *Simmonds F A* The diagnosis of the ruptured achilles tend n Practitioner (Lond n) *179* 56–58 1957

19 *Thompson T C & Doherty J H* Sp ntaneous rupture f tend n f achille a new diagnostic test J Trauma 2 126–1?? 1962

20 *Tobin W J* Repair f negle ted ruptured and severed achilles tend n Ame rican Surge n *19* 514–522 1953

21 *Zadek I* Repair of ll ruptured tend achilles b means of fascia lata J B ne & Joint Surg 2? 1070 1940

FROM THE ORTHOPAEDIC CLINIC, BORÅS
(HEAD: FOLKE STAHL, M.D.)

GASTROCNEMIUS RECESSION

By

FOLKE STAHL

Talipes equinus is, and will probably remain, the most common indication for a surgical intervention on spastic children. The classical lengthening of the Achilles tendon, however, gives in too many cases a poor definitive result. Many cases must be reoperated on account of recurrence, and the risk of talipes calcaneus is not negligible. This method is therefore in many cases unreliable or unsuitable.

One can distinguish two types of talipes equinus among spastic children: one type where the talipes equinus cannot be corrected even when the knee-joint is flexed at a right angle, the other type where the foot can be brought to or past the right angle when the knee is flexed. In this last and largest group the talipes equinus is caused by a contracture in the gastrocnemius. It is then reasonable to disconnect in one way or another this muscle, i.e. to recess it. *Silverskiöld* solved the problem by his transferring of the gastrocnemius origin. *Vulpius* had earlier tried the same thing by dividing the isolated gastrocnemius tendon distally. The results of the Silverskiöld-operation are in some cases very good, while the Vulpius operation by and large has no better effect than the common lengthening of the Achilles tendon.

Luther Strayer (1950) described another type of gastrocnemius recession. Briefly, the operation is performed in the following manner: long curved incision along the calf. One identifies the nervus suralis and keeps it aside, makes one's way medially and laterally between gastrocnemius and soleus and isolates completely the gastrocnemius from all connections with the soleus and with the fascia all the way to the origin of gastrocnemius at the femur. This can be performed by blunt dissection by the finger and usually causes no difficulties. On older children and adults the connections are considerably firmer and may have to be parted by sharp dissection. Then the gastrocnemius part

of the Achilles tendon is separated from the soleus part and cut distally. The gastrocnemius is now completely free from all connections except the origin proximally.

The plantaris tendon is also cut. The foot is flexed to right angle or less and the gastrocnemius is sewn in the new position to the tendon of the soleus with a few sutures. Apply skin suture, plaster cast from toe to groin with the foot in right angle and the knee fully extended. The cast is changed after four weeks when the patient is allowed to get up. He should retain the cast or bandage and nightsplints as long as there is any tendency to flexion in the knee.

Strayer (1958) reported his results and the indications for the operation that he found valid. He regards the procedure particularly indicated for spastic diplegics under six years of age who still can not walk. If such children have walked with more or less improper posture for a long time he feels that his results are poorer. He considers that this is due to the pathologically exaggerated stretch reflexes which have been too firmly established. With the common spastic infantile hemiplegia the operation is always well indicated and an improvement is always to be expected. In athetosis it is not indicated.

During the discussion following *Strayer's* report *Frederic C. Bost* in San Francisco said that at his clinic since 1950 Strayers operation had been used almost exclusively instead of the older lengthening of the Achilles tendon. *Bost* had 177 operations of which [illegible] had been followed up with 88 % excellent or good results.

At the orthopaedic clinic in Borås we have since the autumn of 1960 performed 34 operations according to this method on 21 spastic patients of ages between 4 and 25 years. Of course no definite results can be reported yet. The primary results however have been good in all cases. The most striking feature is the originally unforeseen gains that have been achieved on account of the conspicuously reduced reflex activity.

Not only is the talipes equinus eliminated but there is also *often a* very manifest reduction of the adductor spasm in the hip *and the* flexion tendency in the knee joint and the whole pattern of [illegible] conspicuously normalised. This is probably due to a reduction [illegible] eliciting impulses achieved by the isolation of the [illegible] whereby the intensity of the stretch reflexes is reduced [illegible] vantage is that the risk for talipes calcaneus is eliminated [illegible] diate results of this simple operation have encouraged [illegible] to use it. Follow up studies will be published.

SUMMARY

Gastrocnemius recession was performed in 34 cases of spastic talipes equinus. The preliminary results were good. The method is to be recommended.

RÉSUMÉ

Une résection du gastrocnemien a été pratiquée dans 34 cas d'equinisme spasmodique. Les résultats préliminaires ont été bons. La méthode est recommandée.

ZUSAMMENFASSUNG

Gastrocnemiusresektion wurde in 34 Fällen von spastischem Spitzfuss vorgenommen. Die vorläufigen Ergebnisse sind gut. Die Methode kann anbefohlen werden.

REFERENCES

1. *Strayer, Luther M.*: J. Bone & Joint Surg. 32-A: 671, 1950 and J. Bone & Joint Surg. 40-A: 1019, 1958.

Baker, Frederic C.: J. Bone & Joint Surg. 40-A: 1043, 1958.

3. *Fulford, G. A.*: J. Bone & Joint Surg. 41-B: 68, 81, 1959.

FROM THE ORTHOPAEDIC CLINIC OF THE UNIVERSITY OF ZURICH
(DIRECTOR PROF M R FRANCILLON MD)

DISTORSIO PEDIS WITH AN ISOLATED LESION OF THE LIGAMENTUM CALCANEO FIBULARE

By

MAX R FRANCILLON

Isolated injuries of the Lig calcaneo fibulare following sprained ankle appear to be rare We found it to occur only twice amongst 31 patients who underwent operative correction for habitual or recurring Distorsio pedis

Several publications concerning the findings on the ligaments during treatment of Distorsio pedis at the orthopaedic clinic in Zurich as well as the therapy are available[1] Considerable changes were reported in all cases ligaments proceeding from the lateral malleolus were stretched torn or ripped off often even resorbed In a few cases it was noted that the torn off ligament had found its way into the joint where it caused errosive changes of the joint cartilage we had the impression that with these cases the pain was particularly intense

Ligamentoplasty on the lateral malleolus has been carried out on 27 patients during the last 5 years in addition one patient from the year 1952 was reported on by *Muller & Gschwend* in 1956 3 of the patients had bilateral distorsions therefore in the following table the findings are given for 31 feet for 28 patients

Findings in the Ligaments with Recurring and Habitual Distorsio pedis

	Stretched	Torn or ripped off	Ligament pieces occurred in the joint	Absent
Lig talo fib ant	10	1	6	1
Lig calc fibulare	8	3	1	6
Lig calc talare	2	3	1	2
Lig talo naviculare dors	2			

[1] *Müller & Gschwend* 1956 *Gschwend* 1958 *Francillon* 1959 61 *Kohn* 1961

Two patients demonstrated bilateral habitual distorsions in supination. Exploration revealed merely lax, severely stretched ligaments. *It is possible that these two patients belong to the group with primary* lax ligaments which, according to the finding raised by *B…* comprises about 4 % of the population. It appears certain that this habitual twisting in inversion is often insignificant. We must however be aware of the fact that frequent distorsions can lead to injury of the joint cartilage and especially to the contact surface of the talus. Therefore these injuries should not be regarded as totally insignificant.

With all other patients, recurring distorsions were present in which the initial trauma had occured from … to 30 years previously.

The table shows clearly that, as a rule, the lig. talo-fibulare ant. is most frequently injured. This corresponds completely to the results obtained from the well known experiments on corpses from which it was learned that with inversion in plantar flexion a stretching first occurs followed by tearing and the ripping off; only by continuation of the inversion movement does a tearing of the lig. calcaneo-fibulare occur (*Bonnet, Tillaux, Güttner, Stähli, Leonard, Anderson* et al.).

It should be mentioned that among these *27* cases of post-traumatic recurring Distorsio pedis we found two cases of osteochondrosis dissecans tali … in the sense of a flake fracture as has been reported amongst others by *Roden, Tillegard* & *Lunander, Scharin* and … from *Man, Gschwend* et al.

No discussion of symptomology or diagnosis is required here. They are well known. The great value of X-rays in certain positions is also well known (*Güttner, Cosentino* et al.). They can be of decisive significance for the diagnosis, not however unconditionally, as is demonstrated by cases with an isolated lesion of the lig. calcaneo-fibulare. An isolated lesion of the lig. calcaneo-fibulare was observed twice in 27 cases of posttraumatic recurring distorsion. In one of the … cases it was possible to make the diagnosis pre-operatively; in the other a general diagnosis of a ligament injury was made and only during the operation was it possible to localize the injury to the lig. calc. f… *Inasmuch as the X-rays … in a held position … can give negative results* leading the physician to more or less dismiss the complaints of the patient, these cases appear to be exceptionally important to us. The one case, however, was very instructive for us in that … were able to make the diagnosis, which was confirmed opera… … tating th… *My kinetic examination* with the complain…

The … year old female patient N. K. (H 21,601) wa…

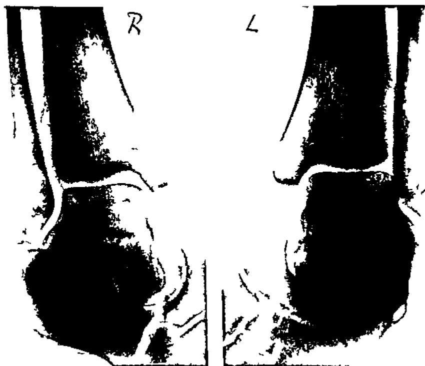


Fig. 1

Distorsio pedis sin. with tearing of the Lig. calcaneo fibulare. N. K. H. 21504. Held X-ray exposure in inversion. No important difference between left and right

by us in October of 1961. For the last 2 years she had suffered frequent twisting of the left foot in supination and probably following a distorsion about which, however, the patient was rather vague. Pain was absent; there was considerable weakness and unsteadiness, however, in walking.

Findings. No impediment in gait. Obvious pedes valgi, slightly stronger on the left. Fibula in the distal tibio-fibular connection on the left slightly more mobile. Bilateral pressure sensitivity in the region of the lig. talo-fib. ant. more pronounced on the left. Pressure sensitivity under the tip of the left lateral malleolus.

X-ray. Even in the held position no incongruence in the talo-crural joint. Joint surface of the tibia and talus completely parallel. The lateral exposure in maximal plantar flexion also revealed nothing abnormal. There was a suggestion of a spreading of the malleolar fork (Ill. 1).

Kinetic examination. Normal behavior of the extensors on both sides

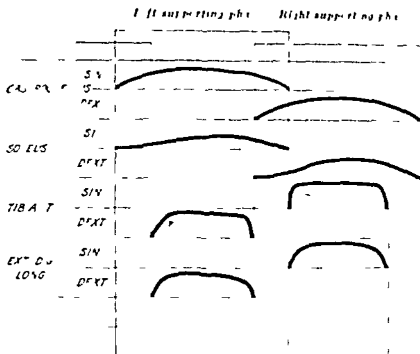


Fig. 2

Distorsio pedis sin. N.K. H 21504. 16 year old female patient.
Myokinesigram 2 years after Distorsio pedis sin. Slight hypergy of the left. The
Action curve of the left tib. ant. steeper.

The action curve of the tib. ant. was however steeper i.e. quicker on the left. No definite abnormality could be found in the action of the gastrocnemius. On the other hand a very slight hypergy of the left soleus was present (III. 2).

The myokinetic finding was therefore rather slight. Both the hypersynchrony of the tib. ant. and extensors as well as the generally considerable hypergy of the triceps surae so often present in these cases of recurring distorsion were absent.

Despite the rather unconvincing kinetic findings, they were sufficiently adequate to allow an objectification of the patient's complaints and to lead us to an assumption of a traumatic induced instability of the talo-calcaneal joint.

This assumption was confirmed during operation. The lig. talofibulare ant. was completely intact. The lig. calcaneofibulare however was torn off from the fibula (N.B. negative X-ray findings on the fibula). In addition the joint between the talus and calcaneus ...



Fig 3
Schematic table of the ligament plasty with corium strip (from *Francillon* Verh Deutsch Orth p Ges 1960)

be opened abnormally wide The ligament still inserted on the calcaneus was resected Thereafter a plastic procedure was carried out with a corium strip conserved in Cialite as is usual in such cases at our clinic

Pathologic anatomic diagnosis Avulsion of the lig calcaneo fibulare Histologically the surgical material consists of a tense fibrous tendonlike tissue On one side the fibrous tracts are often mingled and torn up

Young connective tissue rich in fibrocytes is already sprouting at positions where the ligament was torn (Institute of Pathology of the University of Zurich Chief Prof *E Uehlinger* M D)

In the second case in question (J B H 21517 20 years old) complaints were also made because of pronounced instability which arose after a severe Distorsio pedis of the right foot which occurred 2 years previously The instability was so severe that the foot tipped over into supination 2 or 3 times daily pain set in after one hour of walking and sports activity i e skiing was no longer possible No incongruency in the talo crural joint was demonstrable in the usual held X ray exposure only with abnormal maximal inversion was an indication of incongruency recognizable During operation a completely intact lig talo fibulare ant was found on the other hand the lig calcaneo fibulare was found to be lax and obviously overstretched In this case also a ligamentoplasty with corium strip was carried out

With regard to the accident mechar sm at for these 2 cases it deviated a bit from ion

As a rule Distorsio pedis supinatoria occurs in the equinus position of the foot whereby an overstretching or tearing of the lig. talo-fibulare occurs primarily with or without secondary implication of the lig. calcaneo-fibulare. This mechanism is out of the question for cases like above 2 described. It is much more plausible to assume that the foot was either in a middle position (90°) or in maximal dorsiflexion as it tipped over into inversion. To be sure, in these cases a fracture of the malleolus is more likely to occur than an isolated tear of a ligament.

The operative therapy in these cases is fundamentally the same as in those cases with injury of the lig. talo-fibulare ant. and which has proven successful in all of our cases with but one exception. A corium strip is drawn through the lateral malleolus, one end of which, under sufficient tension, is drawn through a bony canal in the tuberositas met. V and fixed there, while the other end is osseously fastened on the calcaneous. The skin strip is either taken from the patient's thigh or from the cialit skin bank.

Details of technique will not be studied in this paper. The reader is referred to earlier papers from our clinic in which the justification for our preference for the well known method of *Watson-Jones* or its modification by *Imhauser* is presented.

SUMMARY

A report is given concerning operative findings in Distorsio pedis with consideration of the possibility of an isolated injury of the lig. calcaneo-fibulare.

ZUSAMMENFASSUNG

Bericht über operativ behobene Befunde bei habitueller und recidivierender Distorsio pedis unter Hinweis auf die Möglichkeit einer isolierten Schädigung des Ligamentum calcaneo-fibulare.

RÉSUMÉ

Rapport sur les constatations opératoires faites au sujet de lésions ligamentaires des entorses du cou-de-pied. Possibilité d'une lésion isolée du ligament calcanéo-péronéen.

REFERENCES

Bonnet Cit Léger & Olivier

Cosentino R Rev Orthop 49 211 1956

Francillon M R Acta Orthop Belg 25 559 1959

Francillon M R Schweiz Med Wschr *91* 117 1961

Francillon M R Verh Deutsch Orthop Ges 1960

Gschwend N Praxis 35 809 1958

Gschwend N Arch orthop Unf Chir *51* 491 1960

Güttner L Arch orthop Unf Chir *41* 287 1941

Kohn D Arch orthop Unf Chir 5? 593 1961

Léger L & Olivier C Entorses du coup de pied et entorses du genou Masson Paris 1945

Leonard M H J Bone Joint Surg *31* A 373 1949

Mau H Z Orthop *91* 58? 1959

Müller M E & Gschwend N Schweiz med Wschr *86* 1372 1956

Ro len St Tillegård P & Lnander Scharin L Acta Orthop Scand., *23* 51 1953

Stahli W Z Unfallmed Berufskr *38* 190 1945

Watson Jones R Fractures and Joint Injuries Livingstone Edinburgh London 1956

ARTHRODESIS OF THE ANKLE JOINT

By

KNUD JANSEN

The tibiotalar arthrodesis is generally considered an adequate and most useful procedure. It is most frequently applied to two types of disorders. In case of instability due to severe paralysis the intervention may improve the gait and permit discarding of the brace. In painful osteoarthritis following fractures or dislocations in the ankle region remarkable relief may be obtained; however, in such cases an analysis of the conditions also of the subastragular joints must be carried out, as a pan-arthrodesis or perhaps merely a triple arthrodesis is the right answer.

Several authors have stated that we should expect a proportionally high rate of non-unions, as the ankle joint is rather difficult to fuse and the later strain in the region is great. My experience did not differ from this, and the variety and number of procedures recommended do clearly support this conception.

The compression arthrodesis published by *Charnley* in 1951 was therefore studied with keen interest. By this technique Charnley obtained solid union in 1[illegible] out of 19 cases. He could explain the failures by technical errors, such as wrong placement of the nails transmitting the compression force or poor adaption of the resected bone ends.

While I felt the principle of firm compression convincingly sound and correct, his surgical anterior transverse approach with division of nerves, tendons and vessels appeared less attractive. Furthermore this approach did not permit a one-stage pantalar arthrodesis, which traditionally is a common procedure in our clinic. For these reasons I have preferred to combine the Charnley compression method with the surgical approach as described by *Roger Anderson* ([illegible]). According to his report the joint is exposed through lateral and medial incisions and with removal of the malleoli.

This procedure has been tried out in 2[illegible] cases since 19[illegible] and [illegible]



Fig 1



Fig 2

Fig 1 Lateral in sion malleclus exposel
Fig 2 Medical in i ion malleolus removed joint exposel

results and the considerations involved may contribute to the discus sion and to the solution of an important problem

TECHNIQUE

Skin incision

The lateral inci i n is slightl d rsoconvex approximately two inches and a half long from a point a little di tall to the apex of the malleolus and following the po terior edge of the malleolu (lightly anterior to this) The distal end of the fibula is now exposed ubperi ostall damage to the perone l sheath should b avoided The malleclu i rem v d by an oblique o teotomy and by dissection leaving the can ell u urface l ping t ward the j int On the medial side a similar somewhat h rter inci ion curve along the p sterior edge of the malleolus the malleolus is treated like the lateral malleclus and the posterior tibial tendon sheath is pre erved

Resection of cartil ij an l j sit ning f f ot

Through the lateral w und a slice f cartilage and bone is chi elel off the tibia enough to lea e a fre h can ell u plane tran er e t the axis of the tibia Any pr minent l rim r f k j referabl near the d rsal e lge h ul l be carefully rem ved Now the f t i j lace l in the de ire l p iti n and an appr ximately 5 mm s thick se ti n f th trochl a i hi ele l ff leaving a cancell us plain urface parallel to the til ial plate u

The ptimal degr f j lantiflexi n h uld be a light equinu unle s particular circum tance uch a j r n un e l di crej ane f leg length indicate other measure The p iti ning pr blem i de lt with in the di cu i n later In rder to ol tain the c rr ct po ition t m l rec mmen lel t ha the patient pl ced in a supine



Fig. 5

X-ray of ankle with apparatus inserted (tal-tibial fusion)

Painful osteoarthritis following fractures in the malleolar region or following dislocation of the talus was the indication for arthrodesis in 18 cases, while the procedure was applied to seven patients for stabilization of the ankle (polio 6, cerebral palsy 1). These latter groups represent the younger part of the material.

Indication		fracture	polio	cerebral palsy
panarthrodesis	(13)	8	4	1
tal-tibial arthrodesis	(12)	10	2	
previous triple arthrodesis	(3)			

RESULTS

Primary bony union was obtained in 24 cases. In the one case of non-union a re-fracture was apparently provoked in connection with the removal of the compression apparatus and the nail. This procedure was performed in general anaesthesia, and while the course had been smooth prior to this procedure there were constant complaints of pain after this date. The patient was, however, as usual, equipped with a walking cast. When non-union was confirmed after three months re-arthrodesis was performed and solid union achieved after another three months.



Fig 6
X ray of solid pantalar fusion

COMPLICATIONS

In the first years several of the patients had an annoying although not serious infection with drainage from the proximal nail wound The wounds healed spontaneously during the following months Since a sterile bandage has included the compression apparatus such infections have not occurred There has been no infection of the joint region

LATER RESULTS

Among the occurrences after the primary treatment two cases deserve particular discussion

A fifteen year old boy who obtained solid union of the panarthrodesis indicated by polio sustained an apparent re fracture four months after the operation due to a fall Further examination revealed that the lesion was located to the epiphyseal plate Rearthrodesis with the same technique was performed At operation the preoperative diagnosis was confirmed and the epiphyseal plate was removed The later course was uneventful

Another polio patient a Chilean lady aged 38 who previously had an arthrorisis done to stabilize the ankle which was unstable after a severe polio paralysis was discharged without orthopaedic footw

or any other aftertreatment because she wished to utilize her visit to Europe and she left immediately for a tour to Spain and France. She returned six months after removal of the plaster cast with complaint of pain in the midfoot. She had been walking in small light shoes since discharge. By clinical examination and by X-ray a diaphyseal fracture of the fifth metatarsal bone was revealed. Doubtless this was a fatigue fracture. After treatment with a plaster walking cast and fitting with orthopaedic shoes she has no complaints.

Among the other cases there have been no serious complaints. In a considerable proportion of the material, however, some walking pain in the forefoot is recorded, and this problem is apparently significantly greater in the patients who had a pantalar arthrodesis than in the group with tibiotalar arthrodesis.

DISCUSSION

The transmalleolar approach does in my experience offer three definite advantages. Firstly the approach is a minimal trauma to the patient, and locally it is a gentle technique, in particular with reference to the tendons of invertors and evertors of the foot. Next the procedure is easily applied to both tibiotalar and pantalar arthrodesis, and thirdly the cosmetic result with the "lifted" ankle configuration is most agreeable.

The optimal position of the foot regarding degree of plantiflexion is still subject to discussion. In particular to the ladies it may be agreeable to place the foot in moderate or more pronounced equinus which permits the use of shoes with heels. I have used different positions according to my own estimation and to the desire of the patient. If the patient plans to walk on bare feet only a few degrees of plantiflexion are indicated. In one case I adjusted the foot for really high heels to please the patient. Probably she may return some day to have a secondary osteotomy done. In general, however, it should be remembered that the orthopaedic modification of the footwear indicates only a very slight plantiflexion. Otherwise it is impossible to obtain room for the necessary rocker sole.

Whenever the procedure is indicated by instability the choice between tibiotalar and pantalar arthrodesis is merely determined by the evaluation of the supra- and infra-astragular conditions. When the invertors and evertors are paralyzed a pan-arthrodesis should be preferred. In the posttraumatic cases the material does support the view [illegible]

Karlen The pantalar arthodesis does not offer any [illegible] effect This procedure should be preferred only whe [illegible] examination has revealed a manifest disorder of [illegible] joints preferably an osteoarthritis

The aftercare of the arthrodesed patient is obvious [illegible] supply of orthopaedic shoes or adjustment of comm [illegible] be considered part of the treatment The shoes must [illegible] height of the heel and it must be furnished with a [illegible] function This rocker should be designed differently fr [illegible] sal bar as the axis of the rolling action intends to con [illegible] lost ankle function Probably the axis should be locate [illegible] ches above the ankle joint and the bottom of the heel [illegible] porated in the roller circle The tremendous stress is [illegible] strated by the two cases described It may be considered [illegible] dren with remaining epiphyses in the ankle region shou [illegible] with a leather bandage to protect the epiphyses unless [illegible] physeodesis be considered feasible

SUMMARY

The technique of talotibial arthrodesis via transmalleolar [illegible] and application of the Charnley compression apparatus [illegible]

The results in 25 cases are reported Primary union was obt[illegible] in all but one case and in this one case the defective healing w[illegible] rently due to iatrogenic fracture on the occasion of removal of the compression apparatus

The problem of aftercare is discussed and the great stress to the anchylosed foot is emphasized it should be minimized by adequate shaping of the shoe

The optimal position of the foot is in the average case neutral alignment with a few degrees of equinus The particular problem of youngsters with residual epiphyseal plate is also discussed and epiphyseodesis or a protecting leather bandage during the remaining years of growth is recommended

RESUME

Description de la technique de l arthrodese talo-tibiale par rapprochement transmalleolaire et application de l appareil de compression Charnley

Il est rendu compte des resultats obtenus dans 25 cas Une soud

primaire a été obtenue dans tous les cas sauf un chez lequel le défaut de guérison était apparemment dû à une fracture iatrogénique qui s'est produite au moment de l'enlèvement de l'appareil de compression.

Il est discuté du problème des précautions à prendre et l'on recommande de diminuer la pression sur le pied ankylosé par des chaussures de forme appropriée.

Dans la plupart des cas la position optimale du pied est l'alignement neutre avec un faible degré en position de pied équin. Le problème particulier des jeunes chez lesquels la croissance n'est pas terminée est également abordé. Une épiphyséodèse ou un bandage protecteur de cuir est recommandé pendant les années de la croissance qui restent.

ZUSAMMENFASSUNG

Die Technik der tibiotalaren Arthrodese mittels des transmalleolaren Zuganges und die Anwendung von Charnleys Kompressionsapparat wird beschrieben.

Über die Ergebnisse in 25 Fällen wird berichtet. Primäre Vereinigung wurde in allen mit Ausnahme von einem Falle erzielt und in diesem einen Falle war die mangelhafte Heilung augenscheinlich einer iatrogenischen Fraktur, die anlässlich der Entfernung des Kompressionsapparates entstand, zuzuschreiben.

Das Problem der Nachbehandlung wird besprochen und die grosse Beanspruchung des ankylosierten Fusses wird hervorgehoben, weshalb man empfiehlt diese mittels entsprechender Formung des Schuhes möglichst herabzusetzen.

Die beste Stellung des Fusses ist im allgemeinen eine neutrale Einstellung mit wenigen Graden Spitzfuss. Das besondere Problem von jungen Individuen mit noch vorhandener Epiphysenplatte wird ebenfalls besprochen und Epiphyseodesis oder eine beschützende Ledermanschette während der noch übrigen Wachstumsjahre wird anbefohlen.

REFERENCES

Anderson, R.: Journ. of Bone and Joint Surgery [illegible]
Charnley, J.: Journal of Bone and Joint Surgery 33 B [illegible]
Karlén, A.: Acta Orthopaedica Scandinavica [illegible]

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REFERENCES

Anderson, R.: Journal of Bone and Joint Surgery, 27, 37, 1945.
Charnley, J.: Journal of Bone and Joint Surgery, *33 B*, 180, 1951.
Karlen, A.: Acta Orthopaedica Scandinavica, *18*, 175, 1948.

EARLY STABILIZING OPERATION FOR SPASTIC TALIPES EQUINO VALGUS BY GRICE'S EXTRA ARTICULAR OSTEOPLASTIC SUBTALAR ARTHRODESIS

By

J MORTENS H MOLLER and I SALMONSEN

In a previous paper (1) a report was given from the Department for Cerebral Palsy at the Orthopaedic Hospital Copenhagen of the results of orthopaedic surgery on the children operated upon within the years 1950 to 1957 In this paper one of the operative procedures used the Grice operation for stabilizing the severe spastic plano valgus foot is analysed in more detail and results have been compared with the results obtained by the same operation used at department III over the same period for polio paralytic feet and constitutional plano valgus feet in children

In children with cerebral palsy and a moderate to severe spastic paraplegia you frequently see the development of a severe talipes equino valgus In such cases there is persistent equinus in the ankle joint and in the attempt on walking to remain plantigrade the foot is broken into abduction and eversion in the midtarsal joints with [illegible] ous correction of the equinus This development may happen in spite of consistent conservative treatment early bracing and early elongation of the tendo Achillis

The roentgenogram shows the persistent equinus [illegible] in the lateral view indicated by the steep inclination of the talus in relation to the calcaneus and in the frontal view by an increased angle between the longitudinal axis of the talus and the calcaneus [illegible] abduction—eversion deformity of the foot is [illegible] enlarged angle in so far as the normal relation [illegible] calcis and the anterior part of the foot has not [illegible] altered [illegible] contrast to the subluxation of the head of talus in relation to the [illegible] cular bone The steeply placed head of the talus [illegible]

them in eight years Further it will be seen from table 3 that in four cases operation was performed at the age of four but most of them were operated on at the age of eight to nine One case was operated at the age of eleven but her somatic development correlated nine years

TABLE 3

Age at start of conservative treatment duration of treatment and age at operation in 14 children with Cerebral Palsy treated by the Grice operation

Years	1	2	3	4	5	6	7	8	9	10	11
Age at start of conservative treatment	7	3	1			1	1		1		
Duration of conservative treatment	1	2	4	1			4	2			
Age at operation				4		1		3	5		1

RESULTS

The assessment of results is based on a general clinical examination The gait with and without shoes was examined and presence or absence of deformity of feet was noted An x ray examination of the feet following a standard technique was done Further pictures of motion taken at intervals before and after the operation have been evaluated by at least two members of the team The relatives and the physiotherapist have been requested to give their assessment of the results of the operation in regard to walking ability perseverance walking on stairs and playing Support used before and after the operation was noted and on the roentgenograms the condition of the grafts and the position of the talus was examined with measurement of the CT angle

The results of operation on these fourteen children with cerebral palsy were compared with the results after the same operation performed on eight children with paralytic plano valgus feet after polio (nine feet) and on eight children with a constitutional plano valgus foot and a steep talus (fourteen feet) These children were operated on within the same four years period and the follow up was performed on similar lines as for the cerebral palsied children (Table 4)

TABLE 4

Results after Grice s extra articular subtalar arthrodesis in 14 children with Cerebral Palsy 8 with polio paralytic—and 8 with constitutional plano valgus feet

Number of patients/feet	Cerebral Palsy	Polio	Constitutional plano valgus
Good	6/8	4/4	5/6
Improved	9/13	3/3	5/5
Unaltered	3/6	1/1	1/1
Overcorrection		1/1	1/?
Total	14/27	8/9	8/14



Fig 3

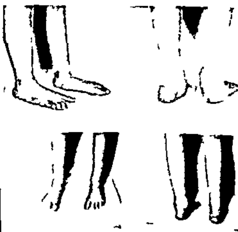


Fig 4

Fig 3 Roentgenograms of the same case as in Fig 1 and 2 one and a half years after the Grice operation

Fig 4 Pre and post operative pictures of the case of spastic talipes equino valgus whose roentgenograms are demonstrated in Figures 1 to 3

In Figures 1 to 4 pre and postoperative conditions on the roentgenograms and on clinical examinations can be seen in a girl with a spastic talipes equino valgus who obtained a good result by the operation

DISCUSSION

These children with spastic di or tetraplegia have more or less severe contractures in their hips and knee joints in the hips flexion inward rotation and adduction deformities and in the knees flexion deformities After a successful subtalar arthrodesis you have to expect a gait with the feet inward rotated and such a gait was also seen more or less marked in all cases as long as the child was wearing its leather brace But in most cases after removal of the support the postoperative training caused a gait with the feet either straight forward or only a little out or inward rotated In two cases however the inward rotation was so severe as to indicate a derotation osteotomy on the femur they are rated as improved in table 4

The dynamic deformities mentioned above especially the flexion deformities of the knees have improved in some cases as judged from the pictures of motion Naturally it is rather difficult to exclude the effect of the postoperative training by the physiotherapists although it is felt that the main reason for the improvement of posture is due to the stabilization of the feet

In four spastic feet we did not get a solid arthrodesis with incorporation of the grafts owing to resorption Two of these cases had to be reoperated and are now placed in the good group while two cases had such solid fibrosis in the tarsal sinus as to keep the foot corrected without reoperation

The results rated as unaltered in the spastic group in table 4 may be due to a combination of factors We may have exceeded the capacity of the operation by interfering with a too spastic inbalanced foot—or the technique may have been faulty In two of these three cases we feel we did not keep the reduced CT angle immobilised for a sufficiently long time by adequate postoperative splinting In the third case an adequate lengthening of the Achilles tendon should probably have been performed during operation He was a boy with a severe spastic diplegia and he had had an elongation of the Achilles tendon years before the operation This elongation was probably insufficient and should have been repeated—but perhaps we in this case exceeded the capacity of the operation An ordinary triple arthrodesis was later performed with fair result

An elongation of the Achilles tendon was performed before or during the Grice operation in five children while in the remaining nine the surgeon did not think it necessary because the foot during operation could be brought in neutral in the ankle joint after the grafts were locked in place At the follow up we found however three cases—rated as improved—who probably ought to have had a moderate elongation of the Achilles tendon performed at the operation The spastic pull of the triceps or shortening of the tendon had caused some abduction deformity of the anterior part of the foot in spite of successful incorporation of the grafts and a well reduced CT angle

CONCLUSIONS

The extra articular subtalar arthrodesis described by Grice can be of help in correcting the spastic talipes equino valgus in such cases where an elongation of the Achilles tendon is not sufficient and where

the child is not old enough to be submitted to the ordinary triple arthrodesis The rate of failures due to resorption or failure of incorporation of the grafts is not very high but reoperation may be necessary in some instances If spasticity is very marked failure or some recurrence of the deformity may take place in spite of incorporation of the grafts In athetosis or ataxia when the child has a plano valgus deformity due to laxity of the ligaments the same procedure can occasionally be of value

SUMMARY

27 feet in children with Cerebral Palsy have been operated upon with the Grice extra articular subtalar arthrodesis Results are reported and compared with the same operation performed on children with a polio paralytic foot or a constitutional plano-valgus foot The technique of the operation is described and the indications for its use discussed

RESUME

27 pieds chez des enfants souffrant de paralysie cerebrale ont éte operes par arthrodese sub talaire extra articulaire d après la methode de Grice Compte rendu des resultats qui sont compares a ceux de meme operation pratiquee chez des enfants ayant un pied paralyse par la poliomyelite ou un pied plano valgus constitutionnel Description de la technique de l operation et considerations sur ses indications

ZUSAMMENFASSUNG

27 Fusse von Kindern mit cerebraler Lahmung wurden mittels der extraatikulären subtalaren Athrodese nach Grice operiert Die Ergebnisse werden vorgelegt und mit der gleichen an Kindern mit poliomyelitischem Lähmungsfuss oder einem konstitutionellem pes plano valgus ausgeführten Operation verglichen Die Technik der Operation wird beschrieben und die Anzeigestellung für ihre Anwendung wird besprochen

REFERENCES

1 *Mortens J & Maller H* Orthopaedic surgery in Cerebral Palsy Danish Medical Bulletin 5 53 58 1958

2 *Grice D S* An extra articular arthrodesis of the subastragalar joint for correction of paralytic flat feet in children J Bone and Joint Surgery 34 A 927 1952

FROM THE ORTHOPAEDIC CLINIC LUND SWEDEN
(HEAD PROFESSOR GUNNAR WIBERG)

OPERATIVE TREATMENT OF PES PLANOVALGUS STATICUS JUVENILIS

Preliminary Communication

By

STEFÁN HARALDSSON

The term pes planovalgus staticus juvenilis designates a condition in which the physiological planovalgus position occuring when the child begins to walk fails to disappear spontaneously during later childhood or becomes more marked When loaded such a foot shows the typical deformity while when unloaded it is at least initially of normal clinical and roentgenological appearance

This is the commonest type of pes planovalgus and in most cases it responds favourably to conservative treatment Some cases however show no tendency to improve despite long treatment with exercises arch supports etc

As is known if this condition with displacement of the foot bones on weight bearing is not corrected in time it will result in deformation of the foot skeleton and joint surfaces together with impairment of the function of the muscles and ligaments Finally the previously corrigible deformities become irreversible with increasing symptoms

Some authors have therefore proposed various operations for those juveniles cases not yielding to conservative treatment (*Miller* 1927 *Hohmann* 1931 *Hoke* 1931 *Young* 1939 *Milch* 1942 *Chambers* 1946 *Niederecker* 1959) These operations are generally regarded as prophylactic their purpose being mainly to induce as normal a further development of the foot as possible

Since 1954 fifty four feet of this type have been operated upon at the Department of Orthopaedics University Hospital Lund

The routine method aims at correcting and preventing the pronated abducted position of the loaded calcaneus but this by lowering of the

sustenaculum tali and the plantar calcaneo navicular ligament supporting the caput tali results in subluxation of the talus elimination of the medial longitudinal arch and abduction of the anterior part of the foot with supination of the first ray We maintain this correction by placing a homogenous bank bone transplant into the tarsal sinus The method is based largely on that described by *Grice* (1952 1955) for talo calcanear arthrodesis which he used in the treatment of pes planovalgus paralyticus



Fig 1

We use cortical bone wedges and place them into the tarsal sinus with the base laterally In order to prevent subluxation and rotation of the talus the lower end of the transplant is placed more ventrally than the upper end We produce an arthrorhisis talo-calcanea preventing pronation abduction of that of the foot under the talus (Fig 1)

In 24 feet the operation was extended to include transposition of the tendon at the tibialis anterior muscle the insertion of which was transposed to the scaphoid bone This muscle is normally both a pronator and a supinator because the direction of its pull coincides with the axes of the subtalar joints (Fig 2 uninterrupted line) The pronating effect may become predominant in pes planovalgus By the transposition the direction of pull of the muscle is turned somewhat medially with the result that its supinatory effect is increased and its pronatory effect decreased (Fig 2 interrupted line) In addition the tendon is attached to the vertex of the medial longitudinal arch and thereby tends to increase the curvature of the latter

As mentioned above all of the patients had first received conservative treatment for long periods (average about 4 years)

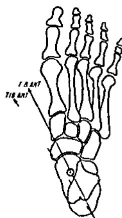


Fig. 2
Essentially after Niederecker

The patients' age at the time of the operation ranged from 3 years 9 months to 10 years 10 months (average 6.3 years).

The interval between the operation and the after-examination varied between 4 months and 7 years; it was 1 year or more for 50 feet and more than 2 years for 34 feet.

Thirty feet had local symptoms before the operation. Of these 21 were symptom-free at the after-examination. The symptoms persisted in 6, but they were less severe than before the operation. 1 foot had more severe symptoms. 2 had been operated upon too recently to permit evaluation.

At the after-examination the loaded calcaneus had a valgus position of 5° or less in 48 feet, which must be regarded as normal (*Lanz & Wachsmuth* 1935). Three feet showed 10–15° valgus, while 3 showed slight varus.

In 51 feet the medial longitudinal arch was less depressed than before operation. In 42 of them the arch was judged as normal, while in 9 it was still partially depressed. In 3 feet the medial longitudinal arch was still completely depressed when loaded.

In the 42 feet where the medial arch was normal, a mean angle of 22° was roentgenologically found between the longitudinal axis of the talus and the floor, a finding in agreement with that of other authors (*Niederecker* 1959).

The mean angle between the talus and the floor in the 9 feet with partial depression of the arch was 30°. In the feet with complete depression of the arch the angle was on the average 36°.

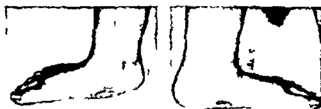


Fig 3



Fig 4



Fig 5



Fig 6

DEMONSTRATION OF CASES

Figs 3 and 4 The operation was performed when the child was 4 years 4 months old Fig 3 shows complete depression of the medial longitudinal arch of the loaded feet before operation Fig 4 shows the reconstructed arches of the feet 2 years 8 months after operation

Figs 5 and 6 The operation was performed at 6 years 4 months The roentgenograms were taken with the foot loaded The talus floor angle before operation (Fig 5) was 35° (right) and 42° (left) At the after examination 2 years 3 months after operation the angles were 25° and 22° respectively (Fig 6)

Figs 7 and 8 Operation at 10 years 4 months Fig 7 shows the preoperative complete depression of the medial longitudinal arch when loaded which is also apparent from the pedogram The calcaneus is pathologically pronated when loaded Fig 8 was taken 4 months after

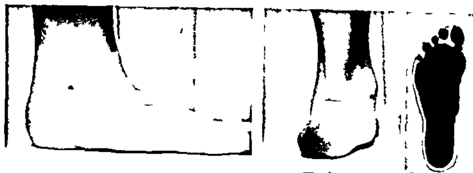


Fig 7

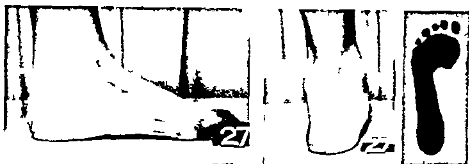


Fig 8

the operation and shows that the medial longitudinal arch has been reconstructed the heel is in normal position when loaded and the pedo gram is normal

SUMMARY

Though most cases of pes planovalgus staticus juvenilis respond favourably to conservative treatment some remain refractory Recent literature shows an increasing tendency to prophylactic operation of such refractory cases

The material consisted of 54 feet of this group operated upon be cause they were refractory to conservative treatment The patients ages at the time of operation ranged from barely 4 to barely 11 years (average 6 3)

Operative procedures Arthrorhisis talo calcanea with homogenous bank bone transplant placed into the tarsal sinus In 24 feet the opera tion also included transposition of the insertion of the Tibialis anterior tendon to the scaphoid

The interval between the operation and the after examination was 4 months to 7 years

At the after examination it was found that of 30 feet with symptoms before the operation 21 were now free of such symptoms The position of the loaded heel was normal in 48 In 51 the depression of the medial longitudinal arch was less marked after operation In 42 of these the curvature of the arch of the loaded foot was judged as normal

RESUME

Parmi de nombreux cas de pieds planovalgus au stade juvenile traites avec resultats favorables par traitement conservateur certains sont demeurés refractaires La litterature recente montre une tendance accrue a l operation prophylactique de ces cas refractaires

Le materiel d observation comprend 54 pieds du groupe opere parce qu ils etaient refractaires au traitement conservateur L age des malades au moment de l operation s etablit entre a peine 4 ans et a peine 11 ans (en moyenne 6 3 ans)

Methode operatoire Arthrorhisis talo calcanea avec transplantation d os homogene place dans le sinus tarsal

Dans 24 pieds l operation comprenait aussi la transposition de l insertion du tendon anterieur tibial au scaphoide

L intervalle entre l operation et l examen complementaire s est etabli entre 4 mois et 7 ans

A l examen complementaire il a ete trouve que sur les 30 pieds presentant des symptomes avant l operation 21 étaient liberes de ces symptomes La position du talon en charge etait normale dans 48 pieds Chez 51 la depression de l arc medial longitudinal etait moins marquee apres l operation Parmi ceux ci la courbe de l arc du pied en charge a ete jugee normale chez 42

ZUSAMMENFASSUNG

Obwohl die meisten Falle von pes planovalgus staticus juvenilis gunstig auf konservative Behandlung reagieren verhalten sich doch einige refraktar Die neuere Litteratur zeigt dass eine zunehmende Neigung besteht solche wiederspenstige Falle prophylaktisch zu operieren

Das Material besteht aus 54 Fussen die operiert wurden weil sie auf konservative Behandlung nicht ansprachen Das Alter der Patie

reichte zur Zeit der Operation von nur 4 bis 11 Jahren (Durchschnitt 6 3)

Operatives Vorgehen Arthrorhisis talo calcanea mit homogenem Transplantat von einer Knochenbank das in den sinus tarsalis eingelegt wird Bei 24 Fussen wurde auch die Transposition des Ansatzes der Tibialis anterior Sehne auf das Naviculare ausgefuhrt

Die Zeitspanne zwischen der Operation und der Nachuntersuchung war 4 Monate bis 7 Jahre

Bei der Nachuntersuchung wurde gefunden dass von 30 Fussen die Symptome vor der Operation hatten 21 frei von solchen Symptomen waren Die Stellung der belasteten Ferse war normal bei 48 Fussen Bei 51 Fussen war die Senkung der medialen Langswolbung weniger ausgesprochen nach der Operation In 42 von diesen wurde die Wolbung des Bogens des belasteten Fusses als normal angesehen

REFERENCES

Chambers E F S An Operation for the Correction of Flexible Flat Feet of Adolescents West J Surg Obst Gynec *54* 77–86 1946

Grice D S An Extra articular Arthrodesis of the Subastragalar Joint for Correction of Paralytic Flat Feet in Children J Bone and Joint Surg 34 A 927–940 1952

Grice D S Further Experience with Extra articular Arthrodesis of the Subtalar Joint J Bone and Joint Surg *37 A* 246–259 1955

Hohmann G Zur operativen Plattfussbehandlung Chirurg *3* 593–595 1931

Hoke M An Operation for the Correction of Extremely Relaxed Flat Feet J Bone and Joint Surg *13* 773–783 1931

Lanz T v & Wachsmuth W Praktische Anatomie J S Springer Berlin 1935

Milch H Reinforcement of the Deltoid Ligament for Pronated Flat Foot Surg Gynec and Obst *74* 876–881 1942

Miller O L A Plastic Flat Foot Operation J Bone and Joint Surg *9* 84 91 1927

Niederecker K Der Plattfuss F Enke Stuttgart 1959

Young C S Operative Treatment of Pes Planus Surg Gynec and Obst *68* 1099–1101 1939

FROM THE CLINICA ORTOPEDICA DELL UNIVERSITA FIORENCE ITALY
(HEAD PROF O SCAGLIETTI)

PLUS VARIANT OF THE ASTRAGALUS AND SUBNORMAL SCAPHOID SPACE, TWO IMPORTANT FINDINGS IN KOEHLER'S SCAPHOID NECROSIS

By

O SCAGLIETTI G STRINGA and M MIZZAU

Among the numerous aetio pathogenic hypotheses that have been advanced in connection with scaphoid osteochondritis of *Koehler* one of the most likely theories is that which ascribes the condition to repeated microtrauma resulting from local static abnormalities through the intermediary of local vascular disturbances Not only is this theory in accordance with the anatomical situation but it is also supported by the fact that the pathological and radiographical aspects show considerable similarity to those of conditions that are known to be due to microtrauma and vascular disturbances

In accordance with this theory and in analogy with what Hulten has written about malacia of the semilunar bone in which he found that the radius extended farther in the distal direction than the ulna (minus variant) we have made a study of the variations of the lengths of the various components of the tarsus and their distances from each other in cases of scaphoid osteochondritis as compared with normal feet No such investigation has been reported in the literature up to now although there have been some authors who have hinted at these aspects (*Brailsford* 1948 reduction of the space between the astragalus and the first cuneiform bone)

MATERIAL

We collected and examined 100 cases of *Koehler s* disease 75 of these were found in the records of the Orthopaedic Clinic of our University from these we selected a group by eliminating cases that seemed somewhat doubtful or where the evolution was insufficiently documented The other 25 cases we found in the literature on osteochondritis

Koehler, we included these because we wanted our material to be more varied especially in regard to possible differences of radiological tech nique

Of the patients concerned 14 were 3 years old 22 were 4 years 24 were 5 years and 35 were 6 years old the remaining 5 patients were younger or older There were 75 male and 25 female patients

In order to obtain normal material for purposes of comparison we have made radiograms of one foot in 100 children who had been hos pitalised for diseases not involving the lower extremities In this way the age distribution was the same as in the pathological group

METHOD

Since generally, we had at our disposal a series of radiograms for every case we selected for our measurements that radiogram in which the fragmentation or increased density was most distinct The indivi dual cases presented no changes of the indices selected with the various stages of development of the diseases (initial stage fragmentation stage etc) only age modified indices

The radiograms which we studied were taken in the anteroposterior projection The patient is seated with the sole of the foot supported flat in the roentgen table that has been placed in the horizontal posi tion the radiation bundle is directed exactly at right angles to the plane of the table

In the radiograms of the foot in the antero posterior projection we

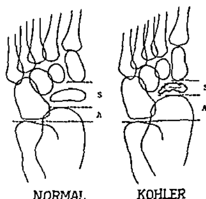


Fig 1

Projection of the astragalus (A) and scaphoid space (S) in the normal foot (left) and in Koehler s scaphoiditis (right) The projection of the astragalus is more pronounced in the pathological case and the scaphoid space is smaller

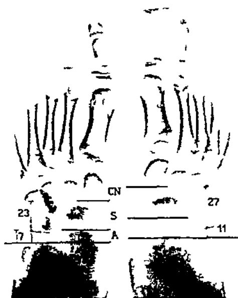


Fig 2

B C A 3 year old boy Comparison of the feet (the right foot affected with Koehler's disease the left one normal) for demonstration of the greater astragalic projection on the affected side — The ratio of the distance from the first cuneiform bone to the calcaneus (CN) and the projection of the astragalus beyond the calcaneus (A) constitutes the so called scaphoid index the greater the space allowed for the scaphoid bone the higher this index Example

On the left (normal)

A = 7 mm CN = 23 mm 23 7 = 3 29 = scaphoid space index (S)

on the right (Koehler's disease)

A = 11 mm CN = 27 mm 27 11 = 2 45 = scaphoid space index (S)

The astragalus projects farther in Koehler's disease (11 mm compared with 7) and the space available for the scaphoid bone is less (2 45 compared with 3 29)

first of all determined the axis of the foot for which we took the extension of the bisectrix passing through the centre of the angle formed by the converging external margins of the astragalus and the calcaneus

Perpendicularly to the axis we have drawn in three straight lines (figs 1 2) each touching the following points the distal limit of the calcaneus the distal limit of the astragalus and the proximal limit of the first cuneiform bone Taking the first line (the one touching the calcaneus) as a basis we have measured the distance from this line to the other two lines (touching the astragalus and the first cuneiform bone respectively) in this way we obtained two values The first value

represents the measurement of the prominence of the astragalus the second that of the limit of the first cuneiform bone We then calculated the ratio of the distance of the first cuneiform bone and the distances of the astragalus and this ratio we have called scaphoid space index This index indicates relatively the distance between the first cuneiform bone and the astragalus i e the space occupied by the navicular bone It is evident that the higher the value of this index the greater the distance between the astragalus and the cuneiform bone the higher index consequently reflects a more favourable situation

FINDINGS

In view of the variability of the astragalus measurements and the other indices with the subjects age we have subdivided the entire material into 4 groups of 3 4 5 and 6 years

For each group we calculated the average astragalic projection and the scaphoid space index with comparison of the normal subjects with the patients with osteochondritis In patients aged 3 years with *Koehler s* disease the astragalus projects on the average 7 mm and the index amounts to 2 63 in the normal foot the astragalus projects on the average 5 8 mm and the index is higher (3 39) Fig 3

In the older age groups the differences between the normal and the pathological values grow larger In the 4 year olds with *Koehler s* di

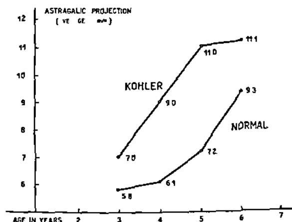


Fig 3

Graph listing the average projection of the astragalus in mm as related to age calculated for 100 cases of Koehler disease and for 100 normal feet The higher line indicates the projection in Koehler s disease the lower line the projection in normal feet

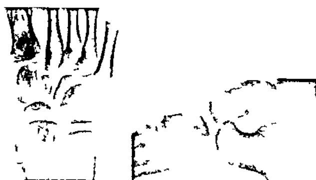


Fig 4
T E 4 ear ld bo N rmal foot A = 6 mm CN = 15 mm S aphoid index 2 5



Fig 5
P A 6 year 11 boy Schaphoid ne ro i of Koehler
A = 14 mm CN = 23 mm S aphoid index 1 6

sease the astragalus projects on the average 9 0 mm in the 4 year olds with normal feet it projects 6 1 mm The scaphoid space indices in these two groups are 2 27 and 2 80 respectively In the 5 year olds the astragalus projects 11 mm in the cases of *Koehler s* disease and 7 2 mm in the normal subjects the scaphoid space indices are 1 88 and 2 73 respectively In the 6–year group the astragalus projects 11 1 mm in *Koehler s* disease and 9 3 mm in the normal children and the scaphoid space indices are 1 81 and 2 1 respectively (Fig 3 tables 1 2)

To sum up in cases of osteochondritis of *Koehler* the astragalus projects farther on the average 3 8–1 2 mm Expressed in percentages this plus value of the astragalus in the pathological foot as compared

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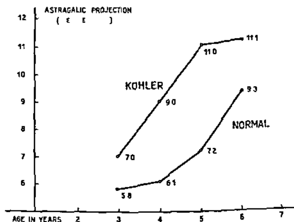


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Fig 4

TF 4 year old bo Normal foot A = 6 mm CN = 15 mm S aph id index 2.5



Fig 5

P A 6 year 11 b y Schaph id necrosis of Koehler
A = 14 mm CN = 23 mm S aphoid index 1 6

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To sum up in cases of osteochondritis of *Koehler* the astragalus projects farther on the average 3 8–1 2 mm Expressed in percentages this plus value of the astragalus in the pathological foot as compared

with the normal foot is 35 % in the 5 year olds, 33 % in the 4 year olds, 18 % in the 3 year olds and 16 % in the 6 year olds.

Our findings further show that the space allowed for the scaphoid bone is less in feet affected with *Koehler's* disease than in normal feet; this difference is particularly pronounced in the younger age groups (up to 1/3 less) and gradually decreases (to approx. 0.2) (fig. 1-2).

TABLE 1
Astragalic projection
(average values 200 cases)

Age	Normal	Koehler	[illegible]
3 years	5.8	7.0	+ 18 %
4 years	6.1	9.0	+ 33 %
5 years	7.2	11.0	+ 35 %
6 years	9.3	11.1	+ 16 %

TABLE 2
Scaphoid space index
(average values in 200 cases)

Age	Normal	Koehl
3 years	3.39	2.63
4 years	2.80	2.27
5 years	2.[illegible]3	1.88
6 years	2.10	1.81

On the basis of the values obtained we determined a threshold of the astragalic projection, i.e. a liminal value beyond which the situation can be regarded as pathological. We regard as the maximal normal projection of the astragalus 6 mm for 3 year olds, 7 mm for 4 year olds, 8 mm for 5 year olds, 10 mm for 6 year olds. Among the patients with *Koehler's* osteochondritis this limit is exceeded by 70 % of the 3 year olds, by 100 % of the 4 year olds, by 90 % of the 5 year olds and by 70 % of the 6 year olds. Over the total number of cases in all 4 age groups, 82 % of those affected with *Koehler's* disease showed an astragalic plus variant.

On the one hand, of the group of normal children the following percentages remained below this liminal value: 70 % of the 3 year olds, 100 % of the 4 year olds, 80 % of the 5 year olds and 65 % of the 6

year olds Over the total number of subjects in the 4 age groups 76 % of the normal subjects had an astragalic projection of less than the pathological threshold

The findings are similar as regards the scaphoid space index with limits fixed on the basis of the average of the measured values we found that 75 % of those affected with osteochondritis had a pathological index

In conclusion it may be stated that from four fifths to three quarters of those affected with *Koehler's* disease presented an astragalic projection and a decrease of the scaphoid space (fig 4) of such a degree that they could be regarded as significant for our investigation Contrastingly only one fifth to one fourth of feet not affected with *Koehler's* disease showed these abnormal measurements (fig 4)

DISCUSSION

As appears from the above this work is based on measurements in millimeters Objections might be made regarding the value of such measurements and the possible influence of variations of certain factors Objections and factors must here only shortly be discussed owing to space limitation

1 The technique of radiographical projection With the central beam exactly at right angles to the plane on which the foot rests a certain value is found a deviation of 10 of the beam has been found to cause considerable changes of the measurements obtained (one fourth one third) It is therefore essential that the projection is perfectly vertical to the plane

2 The measurement on the radiogram An error can be made in drawing in the axis of the foot a 10 degree deviation of the axis leads to an error of 1 mm plus or minus for the astragalus and slightly more for the cuneiform bone

Furthermore the same distances may be measured differently by different investigators If we suppose an error of 1 mm more or 1 mm less (the error will very seldom be greater) for each bone the indices calculated will show a plus or minus variation of one decimal The indices we have found always showed 2–4 times as much difference

3 The position of t e foot Alterations of a certain degree will however result when the f efoot is adducted or bent inward to an appreciable extent but in suc cases the radiogram cannot be used

4 The shape of the f ot A pronounced cavus shape of the foot char

ges the findings so that the astragalus appears to project less and the index is only slightly increased Should we believe that in almost the whole series of 100 cases of scaphoid osteochondritis the feet have been radiographed in a flat position which might have shifted the astragalus forward on the radiogram? The latter explanation might in itself constitute an aetio-pathogenic interpretation but we prefer to believe that our findings are not the result of flatness or cavus posture of the feet but reflect an actual plus variant of the astragalus

5 Age of course has an effect on the measurement of the astragalus and on the scaphoid space index However the age linked modifications always remain within the limits of the normal or of the pathological measurements actually as we have seen every age group of one year has its own average value of astragalic projection and of scaphoid space index the values changing simply into the average values of the next year

6 Stage of development of the disease We observed no correlations between the stage of the diseases (stage of densification stage of fragmentation etc) and the above mentioned values With the passing of the months and the progress of the disease the only change of the values is to be attributed to advancing age

CONCLUSIONS

The measurements which we made in 100 children with *Koehler s* scaphoid osteochondritis divided into age groups (3 4 5 and 6 years) have shown that the astragalus in these cases projects farther than in a similar series of normal children it also emerged that in *Koehler s* disease the space available for the scaphoid bone expressed as the ratio of the distances of the astragalus and of the first cuneiform bone was less than normal These differences may be regarded as statistically significant in view of the uniformity of the case material and of the numerical values of the differences encountered

In the preceding pages we have discussed the objections that might be raised in connection with the validity of our findings in connection with the possible variations resulting from inaccurate projections the position of the foot the differences of measuring on the radiogram In our opinion all these sources of error have been eliminated

The plus variant of the astragalus and the decrease of the scaphoid space are found in the large majority of the cases of *Koehler s* disease

(82 %) but not all The opposite is true of the normal subjects in some of whom pathological values could be observed

The conclusion drawn from these facts is that the plus variant and the decrease of the scaphoid space are anatomical conditions which predispose to the disease and facilitate its development but are not essential requirements

We merely present our conclusion that if our interpretation has been correct there exists in the majority of the cases of *Koehler s* disease an abnormal anatomical condition and in our opinion it is only natural to presume that there is some aetio pathogenic link

SUMMARY

1 In 100 feet of children affected with *Koehler s* scaphoiditis divided into age groups the projection of the astragalus beyond the calcaneus was measured in millimeters on radiograms made in the antero posterior projection by a standardised technique This astragalic projection was found to be greater in the cases of *Koehler s* disease than in 100 normal children

2 The term scaphoid space index is used for the ratio of the distances calcaneus – first cuneiform bone and calcaneus – astragalus This ratio was lower in the 100 cases of *Koehler s* disease than in the 100 normal children

3 Reference is made to the possible sources of error in the finding of these figures projection measuring position of the foot etc

4 It is concluded that the increased projection of the astragalus and the decreased scaphoid space may play a part in the aetio pathogenesis of *Koehler s* disease

RÉSUMÉ

1 Dans 100 pieds d enfants atteints de la scaphoïdite de Koehler repartis en groupes suivant l âge la projection de l astragale derrière le calcaneum a ete mesuree en mm sur les radiogrammes pris en projection antero postérieure selon une methode standardisee On a decouvert que la projection de l astragale etait plus grande dans les cas de maladie de Koehler que chez 100 enfants normaux

2 Le terme indice de l espace scaphoïde est utilise pour indiquer le rapport entre les distances calcaneum – premier os cunéiforme et calcaneum astragale Ce rapport est moins eleve dans les 100 cas de la maladie de Koehler que chez 100 enfants normaux

3 Il est fait allusion aux sources possibles d erreur dan le calcul de ces donnees projection mensuration position du pied etc

4 Il est conclu que la projection accrue de l astragale et la diminution de l epace scaphoïde peuvent jouer un role dans l etude de l etiologie et de la pathogenie de la maladie de Koehler

ZUSAMMENFASSUNG

1 In 100 Fussen von Kindern die in Altersgruppen aufgeteilt wurden und die an der Kohler schen Naviculareeskrankung litten wurde das Vorspringen des Talus uber den Calcaneus hinaus in Millimetern an Rontgenbildern gemessen die in der antero posterioren Projektion gemäss einer standartisierten Technik vorgenommen wurden Das Hervorstehen des Talus war in Fallen von Köhlers Erkrankung grosser als bei 100 normalen Kindern

2 Der Ausdruck navicularer Raumindex wird fur das Verhaltnis der Distanzen Calcaneus os cuneiforme I und calcaneus talus verwendet Die Verhaltniszahl war niedriger in 100 Fallen von Kohlers Erkrankung als in 100 normalen Kindern

3 Die moglichen Fehlerquellen bei der Ermittlung dieser Zahlen Projektion Messung Lagerung des Fusses etc — werden erwähnt

4 Man kommt zu der Schlussfolgerung dass das vermehrte Vorspringen des Talus und der verminderte Naviculareraum moglicherweise eine Rolle in der Atiologie der Kohler schen Erkrankung spielt

REFERENCES

Brailsford J F The radiology of bone and joints London Churchill 1948

Camerer J W Zur Aetiologie der Koehlerschen Erkrankung des O navi ulare pedis Deut ch Med Wchnschr *61* 713 1935

Habboush E J Bilateral disease of the internal cuneiform bone with an associated disease of the right scaphoid bone J A M A *100* 41 1933

Hermodsson I Zur Aetiologie der Koehlerschen Krankheit des Os naviculare Tarsi Acta Radiol *17* 68 1936

Hulten O Ueber anatomische Variationen der Handgelenkknochen Acta Radiol *9* 155–167 1928

Hulten O Ueber die Entstehung und Behandlung der Lunatummalazie Acta chir Scand *76* 121–135 1935

Waugh W The ossification and vascularisation of the tarsal navicular and their relation to Kohler disease Jour Bone and Joint Surg *40-B* 765–777 1958

Zimmer E A Krankheiten Verletzungen und Varietaten des Os naviculare pedi Fortschr Roentgenstr *55* 160 1932